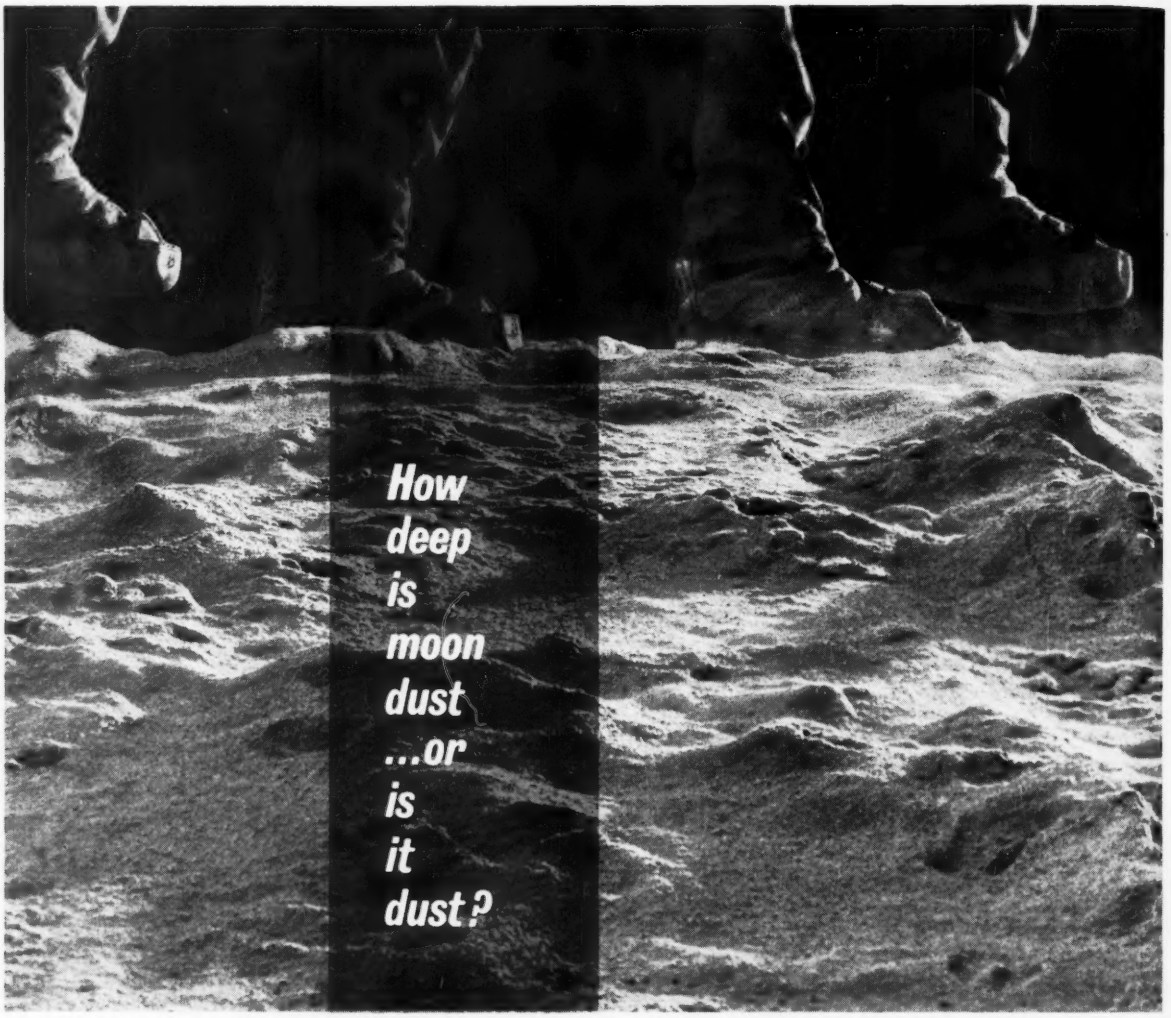
Astronautics

A PUBLICATION OF THE AMERICAN ROCKET SOCIETY

DECEMBER 1961

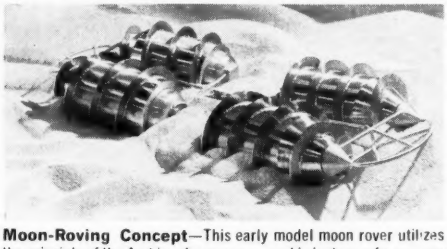
STATE OF THE ART, 1961



GM's DSD seeks an answer!

Scientific studies are now under way in GM's Defense Systems Division to determine the most efficient configurations for lunar-roving vehicles. Major factors under investigation include composition of the lunar surface together with the effects of large temperature ranges, lunar gravity . . . no atmosphere or humidity. Research in our Soils Laboratory on probable lunar conditions has led to a number of promising designs. Unusual studies like these, unusual facilities and unusually capable men present a great challenge and opportunity to scientists and engineers who are qualified to make a solid contribution at any level. DSD is now, as always, searching for new talent in these areas.

Scientific areas now under study: ▪ Aero-Space Operations ▪ Sea Operations ▪ Land Operations ▪ Biological Systems ▪ Technical Specialties



Moon-Roving Concept—This early model moon rover utilizes the principle of the Archimedes screw . . . and is just one of a number of vehicle types under study for known lunar conditions.

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CONTROL ENGINEERS—with experience in such areas as hydraulics, airborne computers, control circuitry, microwave antennas and other areas related to controls for the following areas of work: Missiles & Space Vehicles (attitude control—roll, pitch and yaw); Satellites (orbital control); Radar Tracking (hydraulic control of vertical and azimuth); Control Circuitry (preliminary and breadboard design); Control Systems (adaptive space control systems); Control Techniques (advanced non-linear); Equalization Networks (transistorized); Control Servomechanisms (design and debugging of controls, servomechanisms, sensors and other components); Missile Defense Systems (airborne computers and analog simulations of anti-ballistic missile defense systems).

SYSTEMS ANALYSTS—should be graduate physicists or engineers with a minimum of three years experience in weapon systems analysis, operation analysis, IR, physics of space, signal processing or communication theory. Involves the consideration of many basic problems such as: the proper mix of manned vs. unmanned satellites; the requirements of manned space flight; justification of system choice in terms of cost effectiveness; automatic target recognition requirements for high speed strike reconnaissance systems or unmanned satellites; IR systems requirements for ballistic missile defense; signal processing techniques for interplanetary telecommunications; analysis of weapon systems from conception through development, test and customer use; design concepts for new airborne weapon systems.

CIRCUIT DESIGN ENGINEERS—should be experienced systems engineers capable of analysis and synthesis of systems involving the following types of circuits and components: high power airborne radar transmitters; low noise radar receivers using parametric amplifiers, solid state masers and other advanced microwave components; radar data processing circuit design, including range and speed trackers and crystal filter circuitry; high efficiency power supplies for airborne and space electronic systems; telemetering and command circuits for space vehicles; timing, control and display circuits for COLIDAR (Coherent Light Detection and Ranging).

INFRARED SPECIALISTS—to perform systems analysis and preliminary design in infrared activities involving satellite detection and identification, air-to-air missiles, AICBM, infrared range measurement, air-to-air detection search sets, optical systems, detection cryogenics and others.

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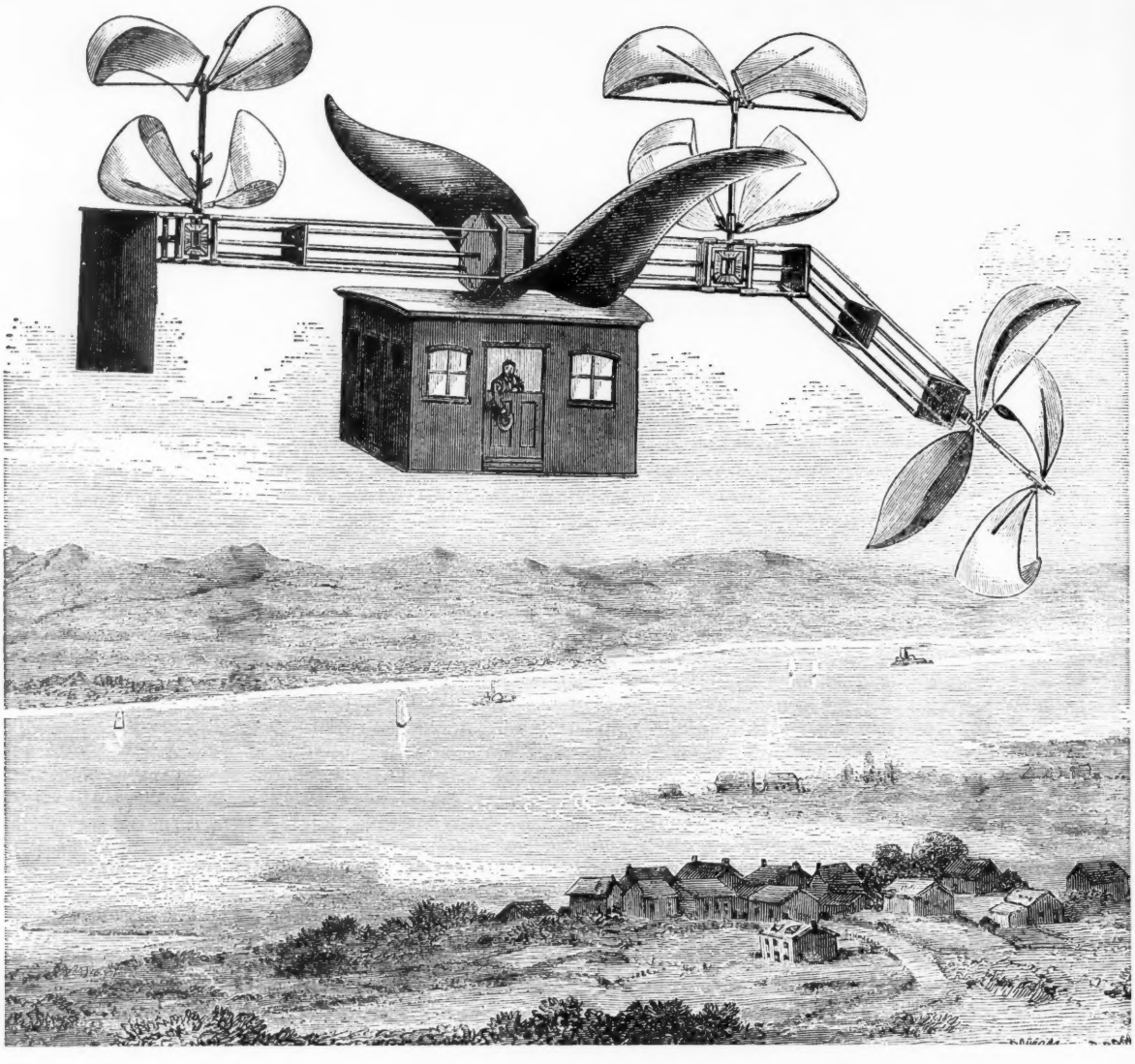
WE PROMISE YOU A REPLY WITHIN ONE WEEK



Nickel would have helped create a helicopter in the horse-and-buggy age

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COVER: "Space Trajectories," a painting by Detroit artist Don Trembath. (ASTRO cover plaques 11 x 12 in. in size are available from ARS Headquarters at $2.00 each.)

Astronautics

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Astro notes

MISSILE GAP

• The long-awaited "missile gap" between East and West has finally materialized—but in reverse. According to the latest national intelligence estimate, the Soviet Union is credited with only 35 to 50 operational ballistic missiles capable of reaching the U.S. at the present time. In contrast, the U.S. has 45 Atlas ICBMs on operational status at this writing, and expects another Atlas squadron and its first Titan squadron (together totaling 18 additional weapons) to come into operation by year's end. Furthermore, the U.S. has five operational Polaris submarines with 80 A-1 weapons plus the *Ethan Allen* in limited operation with 16 A-2 missiles of greater range.

• The new intelligence estimate, reportedly based on "hard new data," is radically at variance with the earlier forecasts of Soviet capability. As recently as the spring of 1959, for example, the Russians were credited with a capability of deploying 100 ICBMs by the end of 1960 and 500 by the end of this year. The ominous implications of this Soviet "lead" were hammered on repeatedly by prominent columnists, politicians, and interested defense contractors to influence the Eisenhower Administration to expand U.S. missile programs.

• Since a Russian lead in long-range ballistic missiles now appears fictitious, several important questions arise: Why were the early estimates so inflated? Why haven't the Russians deployed more ICBMs? What are the consequences of the erroneous estimates?

• One line of conjecture heard in Washington circles is that the Russians never intended to build more than a "finite deterrent," that is, a relatively small force of weapons capable of erasing major U.S. population centers in event of war. An alternative view is that the Russians have been unable to field their ICBM in greater numbers because of its considerable size—estimated at least twice that of Atlas. While their vehicle proved an excellent space booster because of a thrust of 800,000 lb or so, it may have proved highly intractable from the standpoint of deploying it in dispersed, soft sites. (The cost of deploying a single Soviet ICBM might range from four to nine times the cost of deploying a single Atlas in a similar site, according to one estimate.)

• The early U.S. intelligence estimates of Russian ICBM capability were apparently based upon aircraft-industry floor space, trained labor force, expansion potential, and other gross economic parameters. They did not recognize that the pacing item in deploying the missile would be site construction and installation of equipment, and not manufacture of the missile itself. Coupled with this omission was the inevitable tendency of the interested service—in this case the Air Force—to insist upon the highest possible figure.

• Whatever the explanation for the current disparity between Soviet and U.S. intercontinental delivery capability, the Kennedy Administration is firmly convinced of its existence. It was this which prompted Deputy Defense Secretary Roswell Gilpatric to declare earlier this fall: "We have a second strike capability which is at least as extensive as what the Soviets can deliver by striking first." To put the matter another way, the U.S. presently possesses a "counterforce" capability in its present ocean-spanning weapons sufficient to neutralize the bulk of the Soviet retaliatory weapons.

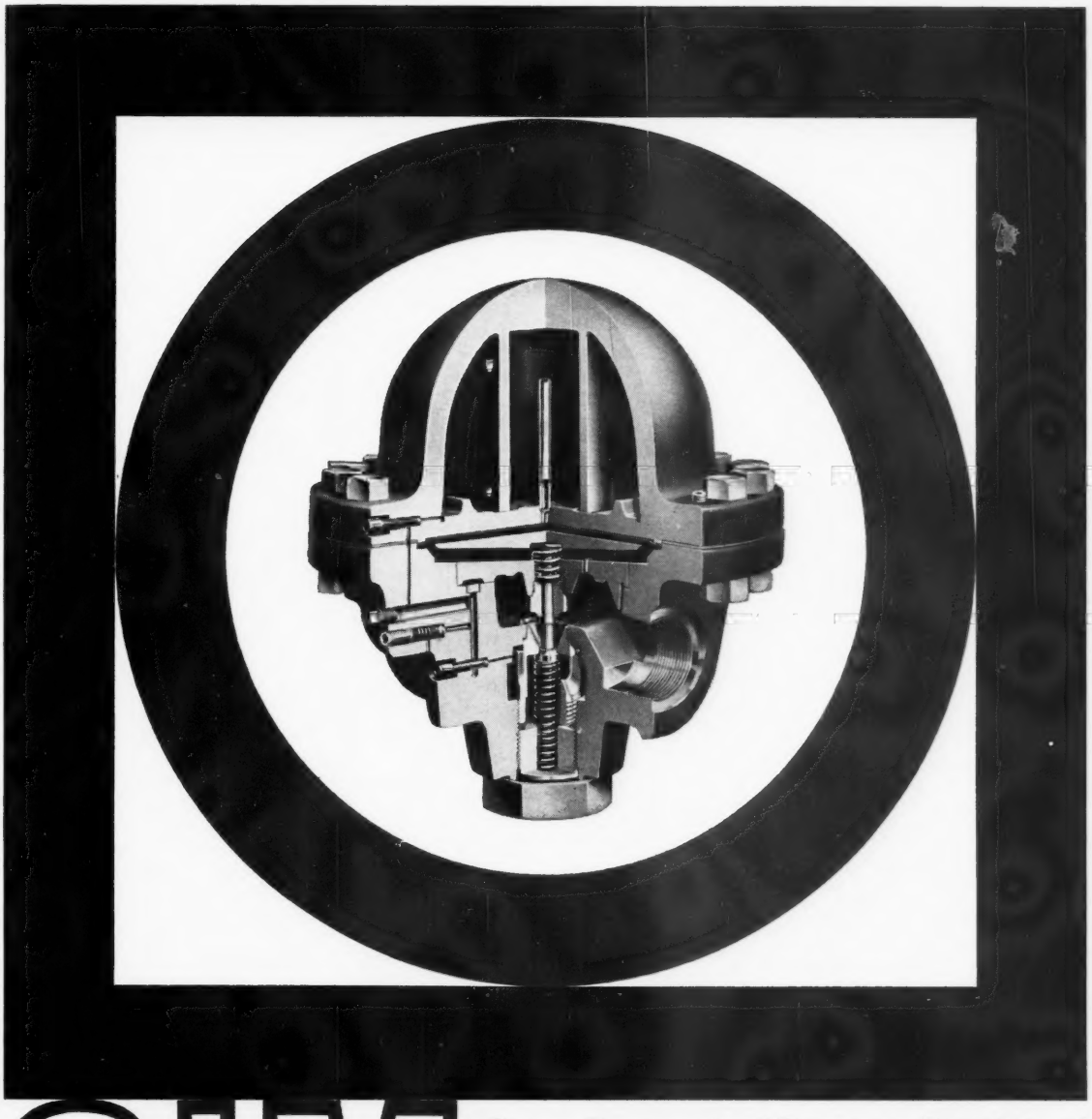
• If the foregoing view of the relative rates of Soviet and U.S. weapons growth is correct, it also helps account for Soviet nuclear-test resumption, the 50-megaton detonation, and the eight-shot missile series concluded in the Pacific in October. Confronted with an existing U.S. weapons superiority, Khrushchev may have ordered the 50-megaton spectacular in an effort to "validate" his own deterrent force in U.S. eyes. (U.S. nuclear experts acknowledge that a warhead of this yield can be held to a 10-ton weight, which is just within the capability of the largest Soviet booster shown to date.) But the major purpose of the prolonged Russian nuclear-test series is more likely the development of a 3- to 5-megaton warhead designed for a new, scaled-down ICBM (perhaps similar to the Titan) which Khrushchev may be pressing in order to offset the growing U.S. missile lead. It is probably this missile which was tested in the Pacific, and not a Saturn-sized booster.

• The ultimate consequences of the erroneous intelligence estimate and the prolonged "gap" controversy are difficult to appraise. While it is gratifying to learn that the U.S., despite its late start, is not trailing the Russians in this vital weapons category, the question deserves to be raised as to whether the U.S. did not unwittingly intensify the arms race by accelerating the Polaris and Minuteman programs on the basis of its erroneous assumptions. Perhaps the vigorous U.S. missile programs strengthened the influence of the "get tough" school inside (and outside) Russia, with the result that Premier Khrushchev was forced to abandon his "peaceful coexistence" line and order a major new weapons-development program to rectify the shortcomings of deploying an oversized ICBM.

MAN IN SPACE

• NASA is expected to order McDonnell Aircraft to proceed with development of an enlarged Mercury capsule for use as an interim space vehicle until the three-man Apollo-A becomes available late in 1964. The "advanced Mercury" will be used to study prolonged space missions (ranging up to one week) as well as to perform rendezvous exercises with astronauts at the controls. A two-man version of Mercury has been proposed, but it's not clear whether NASA will enlarge the spacecraft to this extent. The pacing item in the program is the launching vehicle, either the Atlas Agena-B or the Titan II. These boosters would permit increasing the capsule's orbital weight from the present 2800 to about 4000 lb.

• AF struck out on its attempt to launch a Mercury communications satellite aboard a four-stage Scout from Cape Canaveral. The rocket was destroyed by the Range Safety Officer when it failed to stabilize its course in the first half minute of flight. It carried C- and S-band radar beacons, two telemetry transmitters, two command receivers, and two Minitrack beacons to test the complete Mercury global tracking network. The battery-powered package, placed in a Mercury-type orbit, would have exercised the glo-



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bal network through three or four simulated missions.

• NASA scheduled a mid-November dress rehearsal of the manned Mercury space flight. One of six chimpanzees in training at Cape Canaveral was slated for a three-orbit space ride aboard MA-5. Like Virgil Grissom's MR-4, the orbital capsule was equipped with the explosive hatch, impact bag, and "picture window" so these could be tested for the first time in an orbital re-entry. If the MA-5 flight is a success, MA-6 will follow with a human astronaut in January or February; if the attempt fails, MA-6 will be used to repeat the chimp shot.

• Selection of the Apollo contractor was expected by the end of November with an announcement about mid-December. The Apollo technical subcommittee submitted its appraisal of the five proposals to the Evaluation Board at the beginning of November, but the business subcommittee was still going over the proposals a week later. Companies vying for the billion-dollar plum include the General Electric team, with Grumman, Space Technology Laboratories, and Douglas; General Dynamics with Avco; McDonnell with Ling-Temco Vought and Lockheed; and Martin and North American individually.

• As the final moments of the fiscal 1963 budget making approach, AF generals are once again turning on the heat for a fatter role in space. AF Chief of Staff Gen. Curtis LeMay said the present situation in space is like that prevailing in the air at the start of WW I, when opposing pilots merely waved at one another as they went about their reconnaissance missions. He declared it would be "naive" to expect this to continue and warned that the first nation to develop a manned space system with "complete mission flexibility" could possibly dominate the space above the atmosphere. Maj. Gen. Whisenand, deputy chief of the Systems Command, said NASA's lunar exploration program will not provide all the capabilities required for military operations in space. He said, furthermore, that explorers have traditionally been armed. "I don't know whether or not there are any little green men out there—but we are planning the longest exploration in the history of man—into the greatest of unknowns—and the explorer will be, for the first time, unarmed."

• The supposition that lichens exist on Mars was dealt a heavy blow by Smithsonian botanist, Mason E. Hale Jr. Lichens represent a combination of two forms of primitive life: A parasitic fungus enclosing and protecting a bit of green algae capable of synthesizing food for the fungus through photosynthesis. Although the two forms of life have developed a sturdy symbiosis on earth, they must have existed separately for millions of years before the partnership started, Dr. Hale said. Since fungi require a moist, warm environment with an abundance of organic matter to exist independently, he reasons it is difficult to see how they could have developed and survived on Mars long enough to combine with photosynthetic forms of life.

• With the Thiokol-Reaction Motors XLR-99 engine wide open, the X-15 experimental aircraft rocketed to a record-breaking speed of 4093 mph (Mach 6.04) piloted by AF Major Bob White. Maximum altitude in the flight was about 101,600 ft; flight time was 10 min. The outer windshield cracked again on this flight, cutting off the pilot's view. White landed safely.

• The Bios I space-probe package, prepared by engineers of GE's Missile and Space Vehicle Dept. for NASA-Goddard SFC, got dumped by a malfunctioning booster in a mid-November launch down PMR. Among its several experiments was a payload of giant amoebae. In space, the amoebae were to be freed to feed on paramecia, and then killed with a fixative before re-entry of the Bios I package, which was to be recovered. An autopsy would attempt to reveal any effects of weightlessness on amoebae life processes, by interpretation of their chromosome division. Bios I was to reach an 1165-mi. altitude and undergo about 20 min of weightlessness. Radiation effects are not expected in the amoebae experiment.

NUCLEAR ROCKETS

• The Rover nuclear rocket could be flight-tested as early as 1965 and could reach operational status in 1968 or 1969 as an upper stage of a chemical booster, according to Harold Finger, director of the joint NASA-AEC Nuclear Space Projects Office. Finger estimated Rover will cost something less than $1 billion to develop, of which $241 million has been appropriated through fiscal 1962. The Rover could make possible a direct lunar mission using the C-4 Saturn chemical booster, Finger said. Technical progress with the Kiwi-B prototype rocket will have to be outstanding during the next year if this is to take place.

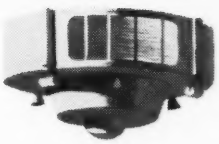
• Hardly had Finger offered his optimistic forecast than the Kiwi-B1A ran into trouble at Jackass Flats, Nev. A hydrogen-gas leak resulted in an explosion injuring five men and destroying the metal shed protecting the prototype reactor assembly. Fortunately, there was no damage to the reactor and no escape of nuclear material.

• The practical ceiling on the Snap reactors developed to date is about 150 kw of electrical energy, according to AEC Chairman Glenn T. Seaborg. Such systems, using sodium-potassium coolant loops and fuel mixtures of uranium and zirconium hydride, are limited to turbine fluid working temperatures of 1300 F and radiator temperatures of 700 F. The result is a weight of about 40 lb per electrical kw in these systems. By going to 1500 F in the radiator, the weight drops to 10 lb per kw, mainly because of radiator shrinkage.

• To approach these new temperature extremes, Seaborg said, a whole new family of materials and conversion devices will be necessary. He forecast a new type of fast reactor for space electrical-propulsion applications. This would use uranium carbide fuel elements and lithium cooling. He also predicted a stepped-up AEC research program on megawatt thermionic systems based on reactors operating near 3500 F.

• NASA's electrical-propulsion program is being moved from Marshall SFC to Lewis Research Center. Harold Finger, head of the Nuclear Space Propulsion Office, will take over as electrical propulsion program manager at NASA Hq. All electrical-propulsion activities at Marshall, which include industrial contracts for system development, as well as flight-testing of engine models, will be transferred as quickly as possible, with the major portion of the work going to Lewis. The Huntsville electrical-propulsion team, headed by Ernst Stuhlinger, will be integrated into the manned lunar-landing program, a top-priority project for Marshall.

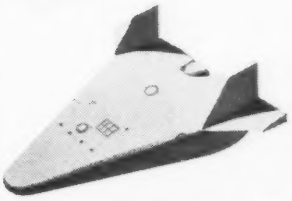
• Despite rumors to the contrary, Dr. Stuhlinger is not planning to leave Marshall at present. He is actively participating in the transfer, which is expected to be carried out without slippage in any of the major steps in the program and



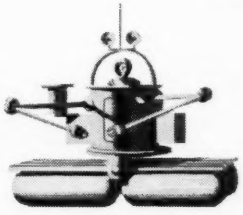
Lunar VTOL Vehicle. A rocket-propelled craft designed to collect lunar ore specimens.

Nuclear Space Ship. An unconventional design by Douglas with living quarters around the ring at the bottom. On landing, it would ease down, ring first.

Nuclear Space Ship. A Douglas design for a space ship with crew quarters and control rooms in the nose, nuclear reactor in the rear.



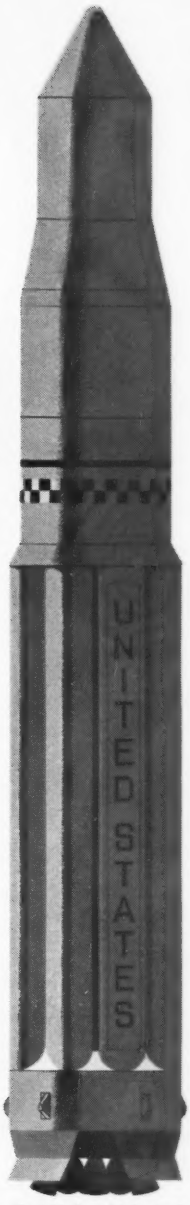
Supply and Escape Vehicle. A compact re-entry vehicle to supply orbiting space stations or to return crews to earth.



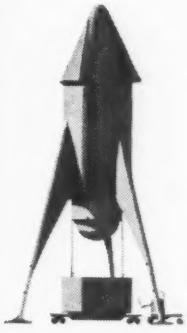
Lunar Service Vehicle. Travels like a "swamp buggy" on inflated rollers. Mechanical arms provided to handle outside chores.

Nuclear Space Ship. A future, medium-thrust, nuclear-electric space ship for one-year interplanetary round trips (Martian and Venusian).

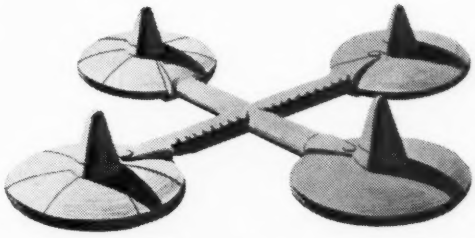
Douglas Thor. Designed as a military IRBM, this dependable missile is the workhorse of the Space Age.



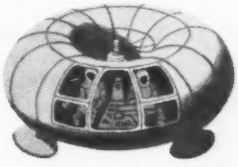
Saturn. First U.S. vehicle designed to put tons of payload into orbit . . . or onto the moon. Douglas-built second stage is as tall as a 4-story building.



Lunar Cargo Handlers. Would load lunar ore samples into containers to be towed back to earth by rockets.



Space Observatory. Sections of this Douglas-designed space station would be sent into space in rockets and be joined together in orbit.



Lunarmobile. Donut-shaped exploration vehicle to use rocket power in space and tractor treads on the moon's surface.

Eleven ways to outwit the law of gravity

When the Space Age dawned, Douglas was ready with specific proposals for space equipment either completed or in advanced stages of development. (Some appear above.)

These Douglas proposals were based on *realistic* estimates of the capabilities of men and materials. They are the valued dividends of the company's considerable experience, gained from the design and production of 30,000 missiles and rockets. These include the Douglas *Thor*, an IRBM which has been totally successful in 89.5% of its tactical and space firings over the past two years.

Today, Douglas looks ahead to other exciting challenges from its firm position of leadership in the conquest of Space.

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without affecting the present contractor structure. Dr. Stuhlinger, chairman of the ARS Electric Propulsion Conference at Berkeley, Calif., March 14–16, will maintain his active interest in the field and will continue to act as an adviser to NASA Hq. on electrical propulsion.

PROPULSION

• The maiden launching of the Saturn SA-I booster was an impeccable performance for any rocket, and near unbelievable for a system as complicated as the SA-I. Yet the monster skimmed through its 10-hr countdown with only two holds (both for weather) and carried out its flight plan almost to the letter. Its eight engines generated 1,296,000 lb of thrust at liftoff, this rising to 1,515,000 lb at burnout, which occurred at 109.4 sec for the inboard engines and 115.15 sec for the outboard engines. Inboard cutoff was scheduled at 111 sec and outboard at 117 sec. The slightly premature cutoff restricted the flight to an altitude of 84.8 mi., a range of 214.7 mi., and a burnt velocity of 3590 mph—compared with a flight plan calling for 90-mi. altitude, 225-mi. range, and burnt velocity of 3700 mph at cutoff.

• In the flurry of congratulations following the success, there was a distinct element of anticlimax. Only two more Saturn flights are scheduled in the next 15 months; and it would not make sense to accelerate them because the pacing item in the C-1 Saturn program is not the booster but the S-IV second stage powered by six Pratt & Whitney lox-liquid hydrogen engines. The S-IV stage is being built and proof-tested by Douglas. The 18 months between now and the first Saturn test with a live second stage (SA-5) might be compressed to 12 if the P&W engines could be delivered earlier; but NASA has rejected this plan because it would mean plundering the Centaur program, which is already behind schedule.

• Saturn is now planned to reach operational status in mid-1964 with the 10th firing. Then it will carry as a payload a substantially complete version of the Apollo-A manned capsule. Two flight tests are scheduled next year, and five test flights in 1963. Live second-stage tests will commence with SA-5, and aerodynamic fins will be added to the Saturn S-I stage. With SA-7, the C-1 will be fully rated to 1.5-million-lb thrust and will commence carrying models of the Apollo spacecraft. In these latter flights Saturn will gross 1.1-million lb at takeoff, compared with 927,000 lb for SA-I.

• At least two new rocket hardware developments are expected to be recommended by the Large Launch Vehicles Planning Group chaired by Nicholas Golovin of NASA. Following up the recommendation that the C-4 version of Saturn be used as the primary lunar vehicle, relying upon a single rendezvous to assemble the requisite payload in earth orbit, it appears likely that a new high-energy upper stage will be necessary for the C-4, probably based on a single-chamber lox-liquid hydrogen engine of 1.2- to 1.5-million-lb thrust. Should this development be ordered, the S-II Saturn stage of 800,000-lb thrust presently assigned to North American may be sharply modified.

• The other hardware development to be requested by the group may be a solid-propellant stage suitable for clustering into a Nova-sized rocket capable of the direct lunar expedition. AF is particularly anxious to develop a 120- to 160-in. solid booster capable of orbiting a 17,000-lb Dynasoar. It has proposed strapping such solids to the Titan II, but an all-solid stage seems more feasible.

• NASA ordered 14 more Thor-Delta boosters from Douglas Aircraft. The vehicles will use the Rocketdyne MB-3 engine uprated to 170,000-lb thrust, plus a pair of 1000-lb-thrust vernier engines. The new Delta vehicles will also be 4-ft shorter than their predecessors. They will be used mainly to launch communication and Tiros weather satellites.

• Aerojet General and Rocketdyne received $185,000 NASA contracts to "brainstorm" the problem of unconventional liquid engine and vehicle-design concepts. The goal of these studies would be very large space rockets of high reliability that can be developed and manufactured at significant savings. Thrust range under consideration is 2- to 24-million lb.

• NASA is buying 13,500 acres in southwest Mississippi some 35 mi. from the Michoud Ordnance Plant at New Orleans, La., for the erection of a half-dozen test stands suitable for testing booster stages ranging up to 20-million-lb thrust. The space agency is also acquiring easements on an additional 128,000 acres of pine timberland surrounding the static-test facility. Land acquisition will cost about $13.5 million, NASA estimated. It said the new facility for Saturn- and Nova-class boosters will eventually employ 500 to 1000 engineers, technicians, and supporting personnel.

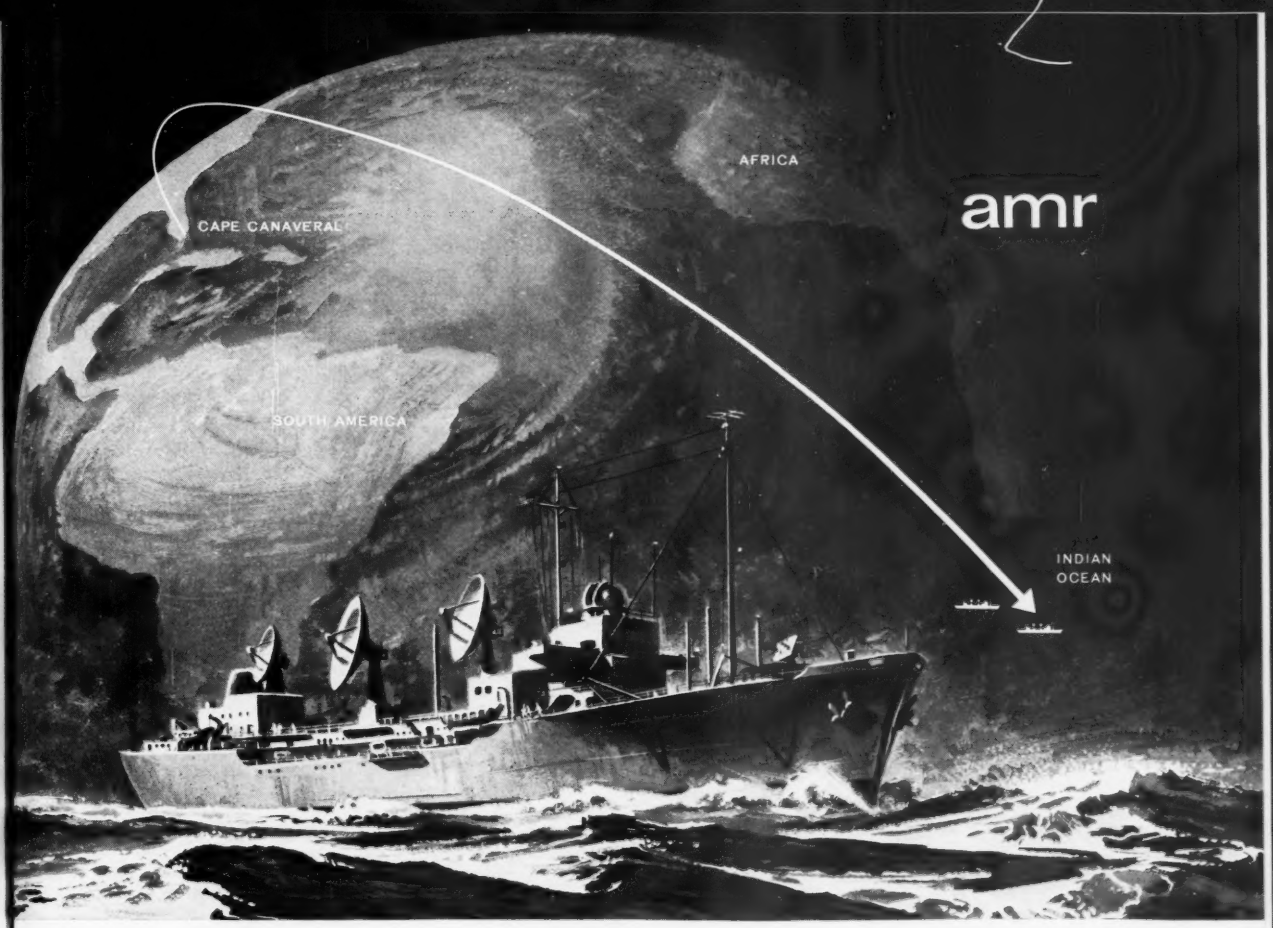
• NASA-Marshall awarded Hughes Research Laboratories a supplemental $1,758,258 for continued research and development on cesium-ion engines. This brings the Hughes funding on cesium engines to $2,656,712.

• The same SeaBee rocket launched underwater from a floating platform at the Naval Missile Center, Pt. Mugu, Calif., on October 24 was run through another underwater-launching test November 2. The liquid-propellant SeaBee is a slightly modified Aerojet-General Aerobee-100 rocket measuring 17 ft long and 15 in. in diam and having a thrust of 2600 lb. More than 40 successful launches of solid and liquid (the two SeaBees) rockets have been made by NMC under its Hydra program, which aims at demonstrating the ability to launch very large space vehicles from floating platforms, that is, water launch of large rockets for space missions.

ORGANIZATION

• NASA touched off a nationwide recruiting drive for 2000 scientists and engineers to staff the manned lunar-landing program. The figure is based on the needs of all of NASA's field centers, according to Administrator James Webb. He said special teams of NASA scientists will visit virtually every area of the U.S. to interview candidates in the next few weeks. NASA particularly wants personnel experienced in fluid and flight mechanics, materials and structures, propulsion and power, data systems, flight systems, measurement and instrumentation, experimental facilities and equipment, space and life sciences, and project management. Salaries range from $6345 to $21,000, depending upon qualifications and experience.

• NASA filled out several more top positions in its reorganized headquarters staff. Within the Office of Manned Space Flight, headed by D. Brainerd Holmes, Nicholas E. Golovin has been named director of Systems Engineering; Charles H. Roadman, director of Aerospace Medicine; George M. Low, director of Spacecraft and Flight Missions; Milton W. Rosen, director of Launch Vehicles and Propulsion; and William E. Lilly, director of



Objective: increase capability of the Atlantic Missile Range – sponsored by the Missile Test Center of the Air Force Systems Command – to study missiles and space vehicles during the critical terminal phase of flight with a refinement never before possible. Prime requisite: *mobility* . . . ability to move to the most advantageous position in thousands of miles of ocean.

The answer: conversion of two large troop transports into Mobile Atlantic Range Stations, seagoing laboratories incorporating every proven technique of instrumentation, data acquisition, and instantaneous data transmission to Cape Canaveral, integrated with the most sophisticated long range tracking radars. System Manager: The Sperry Rand Systems Group. General Offices: Great Neck, N. Y.

Mobile Atlantic Range Stations will be equipped with integrated radar, telemetry, infrared tracking, data handling, communications, inertial navigation, and sophisticated weather forecasting. Team members include Bethlehem Shipbuilding, Ford Instrument, Gibbs & Cox, IT&T, Remington Rand UNIVAC, Sperry Gyroscope Company.

SPERRY

Program Review and Resources Management.

• Edgar M. Cortright became deputy director of the Office of Space Sciences under Director Homer E. Newell, with Thomas Smull to direct the Office of Grants and Research Contracts; Donald H. Heaton, director of Launch Vehicles and Propulsion Programs; John F. Clark, director of Geophysics and Astronomy Programs; John D. Nicolaides, director of Program Review and Resources Management; and Oran W. Nicks, director of Lunar and Planetary Programs.

• In Advanced Research and Technology, Newell D. Sanders was named technical program coordinator to Director Ira H. Abbott, with Harold Finger directing Nuclear Systems, John P. Stack handling Aeronautical Research, and Milton B. Ames Jr. managing Space Vehicles. No director was appointed for the Office of Applications, but Morton Stoller was named deputy director with Morris Tepper handling Meteorological Systems and Leonard Jaffe directing Communications Systems.

SPACE TECHNOLOGY

• A Titan I launched from Cape Canaveral was successfully detected some 90 sec after liftoff by the Midas IV early-warning satellite in a test performed in October. Word of the detection was relayed from the Midas to a tracking station at Vandenberg AFB several hours later, on the satellite's next pass over the U.S. (Readouts from an operational system would be scheduled more promptly, of course.) The success of the infrared sensors of Midas IV confirmed earlier experiments conducted with Midas III.

• Somewhat less successful was the West Ford experiment carried into a 2100-mi. circular orbit aboard Midas. Although a telemetry signal was received indicating that the 75-lb dispenser of the hair-like copper dipoles had been ejected from the satellite, the needles were never discovered by subsequent radar search. They were imbedded in a binder which was supposed to evaporate in space and gradually spread around the globe in a 5-mi.-wide band at the rate of 1200 mi. per day. One possibility is that the West Ford cylinder failed to tumble, with the result that the dipoles are traveling together as a single tight clump instead of spreading out into a band.

• The worldwide clamor over the West Ford experiment reached extremes as launch time approached. Britain's Professor Fred Hoyle called it an "intellectual crime"; Sir Bernard Lovell called the shot a "stain" on the U.S. space research program; Danish astronomer K. A. Thernoe said the shot was designed for military and not scientific purposes. It was apparent that the strongest critics were unfamiliar with the careful studies preceding the shot, while the more restrained critics feared that West Ford, although not dangerous in itself, might lead to future projects interfering with optical and radio astronomy.

• NASA secured 30 min of telemetry data from the P-21 ionosphere probe launched to an altitude of 4261 mi. aboard a Scout rocket from Wallops Island. The 94-lb package obtained a daytime profile of the ionosphere. It will be followed sometime next year with a similar shot at night. In another Wallops shot, an Argo D-4 rocket carried an experimental U.S.-Canadian "topside sounder" package to an altitude of 560 mi. to check its operation in the ionosphere. The sounder is scheduled to be launched by a Thor-Delta from Cape Canaveral next year.

• AF recovered the capsule of Discoverer 32 in an air catch after a day in space, failed to orbit No. 33 because of a problem in the Agena-B stage, and successfully orbited No. 34 but failed to recover it because of an in-orbit failure of the satellite. The spotty record brought to 10 the number of capsules re-entered and nine actually retrieved. It brought to 23 the number of Discoverers successfully orbited, for a 67% average.

• Because of the failure of No. 33, NASA delayed its Ranger II scientific space probe until the trouble could be diagnosed. (Both Ranger and Discoverer use an Agena-B upper stage.) Delays with Discoverer 34 were caused by a passing freight train which jiggled the guidance system. This effected a further Ranger postponement into the latter half of November.

COMMUNICATION SATELLITES

• A plan for operation of a commercial communication-satellite system by a group of international common carriers came under fire from Sen. Russell Long (D., La.) during hearings of the Senate Small Business Committee. The common carriers devised the plan to conform to guidelines from the FCC. It provides for a nonprofit corporation to own the relay satellites, but with each carrier owning its own ground stations and conducting its authorized service. Lee Loevinger, director of the Justice Dept.'s Anti-Trust Div., said the "generalities and omissions" of the carriers' plan would have to be filled in before Justice could approve it. Sen. Long was unhappy at the idea that the carriers could pass along any losses into their rate bases.

INTERNATIONAL

• The European Space Launcher Development Organization (ELSDO) plans to launch its first satellite in mid-1965 from Woomera, Australia, using a three-stage vehicle based on Britain's 300,000-lb-thrust Blue Streak, a French second stage, and a German third stage, both probably liquid. The vehicle is to have an orbital payload of 2000 lb if the final stage uses conventional propellants, and 3000 lb if it uses cryogenic hydrogen and oxygen. The vehicle timetable, set by a nine-nation conference of ELSDO members in London, provides for initial test flight of the Blue Streak in 1963. Total cost of the all-European booster program is reckoned at $196 million.

• A space booster of this caliber would keep the European community within reach of its own communication-satellite system, should they feel left out of others. As the British Minister of Aviation, Peter Thorneycroft, commented, "Our object is to avoid a situation in which Europe is right out of the launching of any satellites in the future . . . It gives us the opportunity, which otherwise would be denied us, of taking some part in the commercial exploitation of space."

• Scientists from 28 nations, including Russia, Poland, and Czechoslovakia, were scheduled to attend a 10-day workshop in Washington on the uses of satellite information in developing weather forecasts. The program includes visits to NASA and Weather Bureau installations, laboratory sessions to practice using Tiros photos and radiation data, and access to U.S. specialists for discussion of special problems. The three Tiros satellites launched to date have obtained about 70,000 useful cloud pictures, the Weather Bureau said.

♦♦

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For the record

The month's news in review

Oct. *2*—AF successfully fires Atlas-E 5000 mi.

—ARS announces election of William H. Pickering, JPL director, as president for 1962.

Oct. *3*—State Dept. bars Soviet space scientists from ARS Space Flight Report to the Nation symposia. Reason: Soviets have not invited American scientists to attend similar space meetings in Russia.

Oct. *4*—Soviets disclose at IAF Congress that Cosmonaut Gherman S. Titov became sick under the stress of weightlessness during his 25-hr space flight last August.

—Advanced A-2 Polaris is fired more than 1500 mi.

—X-15 is flight-tested minus bottom stabilizing fin.

Oct. *5*—Atlas hits on target 9000 mi. away in Indian Ocean. Mark IV nose-cone model is recovered.

Oct. *7*—Nike-Zeus test flight fails when second stage explodes 2 mi. in atmosphere.

—USSR launches fourth multistage rocket 7500 mi.

—French plan National Space Studies Center.

Oct. *9*—ARS Space Flight Report to the Nation opens at N.Y. Coliseum.

Oct. *11*—AF Maj. Robert M. White flies X-15 to record 215,000-ft altitude and speed of 3647 mph.

Oct. *13*—AF launches Discoverer 32 into polar orbit.

—Committee of international communications companies set up by FCC last July recommends formation of nonprofit corporation to develop and operate a commercial system of communications satellites.

—USSR fires fifth multistage rocket 7500 mi.

Oct. *16*—USSR fires sixth multistage rocket 7500 mi.

Oct. *17*—NASA pilot Joe Walker flies X-15 to record 3920 mph.

Oct. *18*—NASA Aerobee-Hi payload tests behavior of liquid hydrogen in zero gravity.

Oct. *19*—NASA fires four-stage Scout to 4261-mi. altitude in ionospheric study.

Oct. *21*—AF Project West Ford gets off auspiciously with launching into polar orbit of Midas IV satellite carrying Project Needles piggyback.

Oct. *23*—Soviet Union claims it has solved the problem of antimissile defense—destroying a missile in flight.

—Advanced A-2 Polaris successfully fired from submarine 90 ft beneath Atlantic to more than 1000 mi.

—Discoverer 33 satellite fails to orbit when second-stage rocket shuts off too soon.

Oct. *24*—Orbiting Midas IV "spy-in-the-sky" detects Titan firing in less than 2 min. after blastoff.

Oct. *25*—NASA postpones Ranger II shot indefinitely.

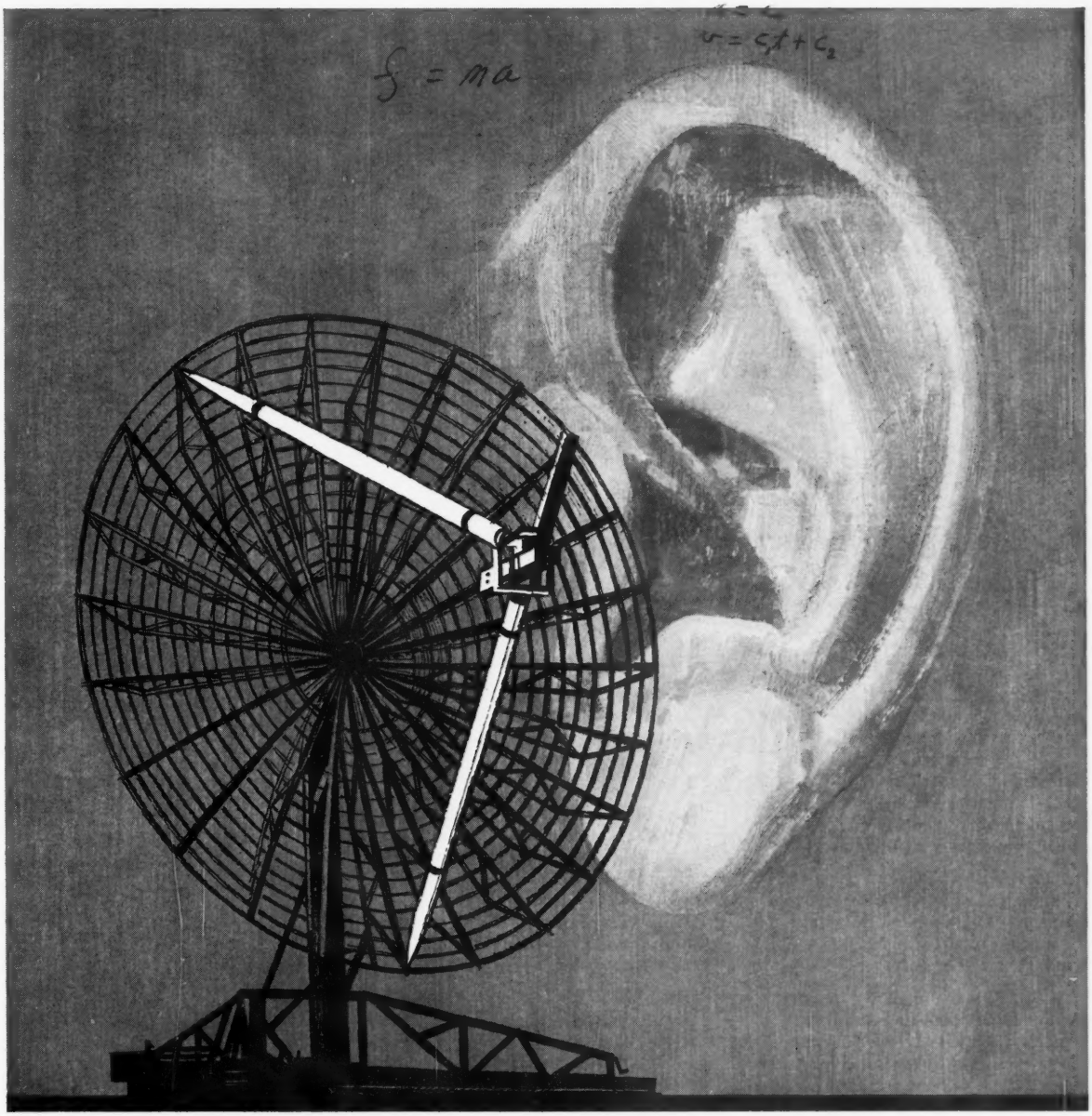
—AF reports it is unable to establish radar contact with Project Needles.

Oct. *26*—AFCRL successfully flight tests "largest" plastic balloon 318 ft in diam and 434 ft long.

Oct. *27*—First NASA flight test of eight-engine Saturn is success. Rocket reaches 84.813-mi. altitude, top speed of 3607 mph, and zooms 214.727 mi. into Atlantic in 8 min 3.6 sec after launch. Superbooster delivers 1,296,000-lb thrust on liftoff and 1,515,000 lb just after engine cutoff. Four center engines burn 109.37 sec; four outboard engines, 115.15 sec. ♦♦

New NASA-Marshall SFC Central Lab and Office

Electronic and Missile Facilities, Inc., of New York City will construct a new Central Laboratory and Office Facility at the NASA Marshall Space Flight Center in Huntsville, Ala., under a recently awarded $3.99-million contract. In addition to general facilities, such as a 400-seat auditorium, the building will house Marshall's Aeroballistic and Research Projects divisions and offices of the director, operations analysis, general counsel, Saturn systems, light and medium vehicles, weapons systems, future projects, technical program coordination, technical services, management services, procurement and contracts, financial management, launch operations directorate, and public information. The Central Laboratory and Office Facility should be ready late in 1962.



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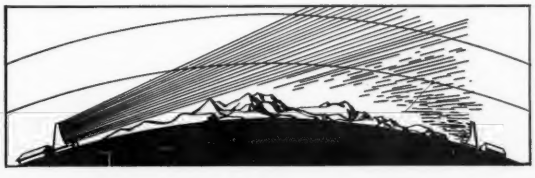

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People in the news

APPOINTMENTS

Samuel Herrick, ARS director and professor of astronomy at the Univ. of California, has been appointed Jerome Clarke Hunsaker Visiting Professor of Aeronautical Engineering at Massachusetts Institute of Technology for the academic year 1961–62.

Peter L. Nichols Jr., chairman of the ARS Propellants and Combustion Committee and former director, Space Sciences and Propulsion Div., Stanford Research Institute, has been appointed senior scientist at Aerojet-General's Solid Rocket Plant.

J. Donald Rauth, formerly vice-president of Martin Co.'s Nuclear Div., has been named to direct the company's ICBM-space booster programs and will be in charge of the entire Titan project, including activation of the near-operational Titan I, production and test of the advanced Titan II, and continued development of Titan II. **Ralph D. Bennett,** formerly director of research, has been appointed a vice-president and will succeed Rauth as general manager of the Nuclear Div.

Harold Rind, formerly head of environmental control and cryogenics, Republic Aviation, has been elevated to chief of the company's Space Environment Laboratory.

At IBM's Federal Systems Div., **Arthur E. Cooper** has been made manager of research and engineering and **Raymond A. Soderberg** has been named director of operations planning.

James F. Healey has been appointed vice-president of Minneapolis-Honeywell's Aeronautical Div. Healey is general manager of the division's St. Petersburg, Fla., plant.

Harold L. Flowers, formerly director of weapons systems, Goodyear Aircraft Corp., has been appointed general manager, engineering, Electronics Operation, Avco Electronics and Ordnance Div.

David C. Goldberg and **Roger A. McIntyre** have been appointed director and associate director, respectively, of the new Space Materials Dept. at Westinghouse Electric Corp.

Max E. Norman, Richard W. Knight, and **Benton H. Brothers** have been named to head the Heavy Military Equipment Dept., Avionics and Electronics Dept., and the Chemical Operations Dept., respectively, at Universal Match Corp.'s Armament Div.

G. J. Harbold has joined the Life Science Dept., Naval Missile Center, Headquarters Pacific Missile Range, as bio-project acoustics director.

Richard C. Stricker has been appointed manager of range bases for Pan American World Airways' Guided Missile Range Div. at Patrick AFB, Fla.

David Shore, formerly associate director, RCA's Advanced Military Systems Group, has been made program manager for RCA's role in Project Saint. **D. C. Arnold** becomes chief engineer for the Aerospace Communications and Controls Div., Defense Electronics Products.

Ralph P. Hudson has been appointed chief of the Heat Div. at the National Bureau of Standards, succeeding **Charles M. Herzfeld,** recently appointed an associate director of NBS and who is now on a year's leave of absence serving as assistant director of ARPA. **Yardley Beers** has been promoted to chief, Millimeter-Wave Research Section, Radio Standards Laboratory, Boulder Laboratories, and **William A. Wildhack** to an associate director of NBS.

J. L. Bromberg has been appointed assistant general manager of Douglas Aircraft's Missile and Space Systems Div. and also director of the division's Skybolt Systems Subdivision. **R. L. Johnson** has been upped from director to vice-president, product development, in the division.

Lawrence L. Kavanau, formerly manager, aerospace sciences, Space Systems Operations, Aeronutronic Div., Ford Motor Co., has been appointed special assistant for space in the Office of the Director of Defense Research and Engineering, Dept. of Defense.

Kazuo Alan Yamakawa has joined Electro-Optical Systems, Inc., as head, Materials Research Dept., Quantum Physics Div., and **Leslie J. Cook,** as manager, Fluid Physics Div.

Arthur R. Matheson has joined General Atomic Div., General Dynamics Corp. as manager, materials applications.

Hiden T. Cox has been appointed assistant administrator for NASA public affairs. Dr. Cox is on leave of absence as executive director of the American Institute of Biological Sciences.

James C. Callaghan has been promoted to manager of the operations staff, Space Systems Operation, Aeronutronic Div. of Ford Motor Co. He formerly was manager, Organization Planning Dept.

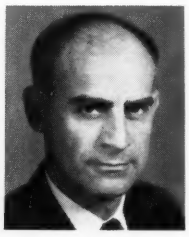
Joseph M. Brown has been appointed associate department head, Vehicle Systems Dept., Systems Research and Planning Div., Aerospace Corp.

S. E. Weaver has been promoted to vice-president, engineering and marketing, Marquardt Corp. He formerly was vice-president of marketing. ♦♦

Herrick

Nichols

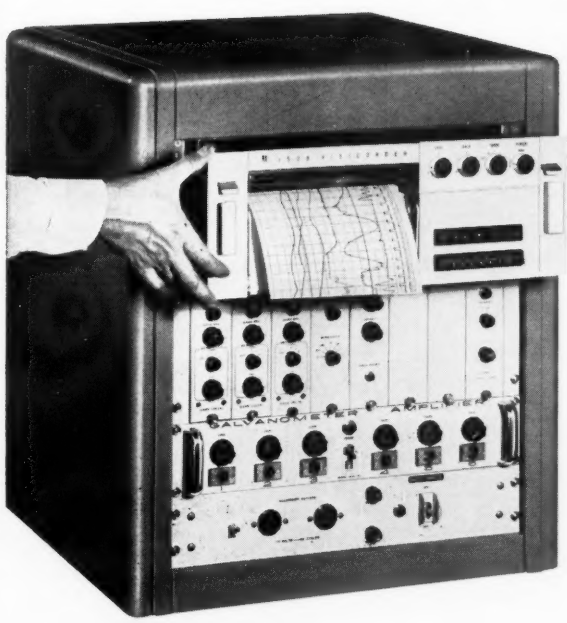
Healey

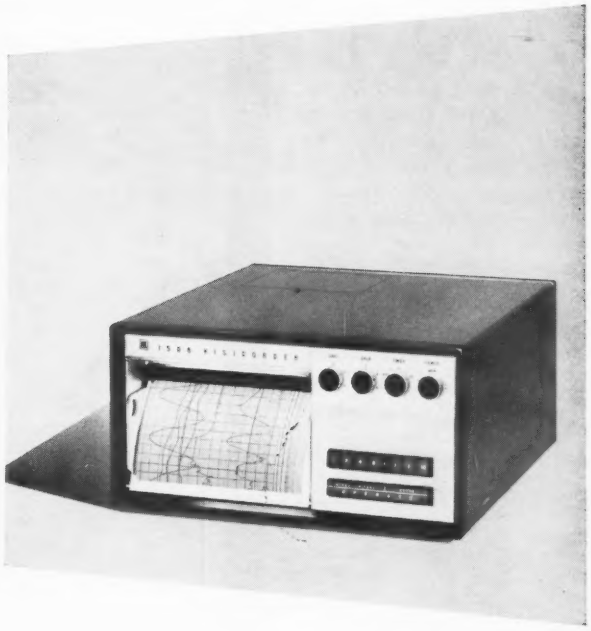


Flowers

Shore

Bromberg





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Honeywell

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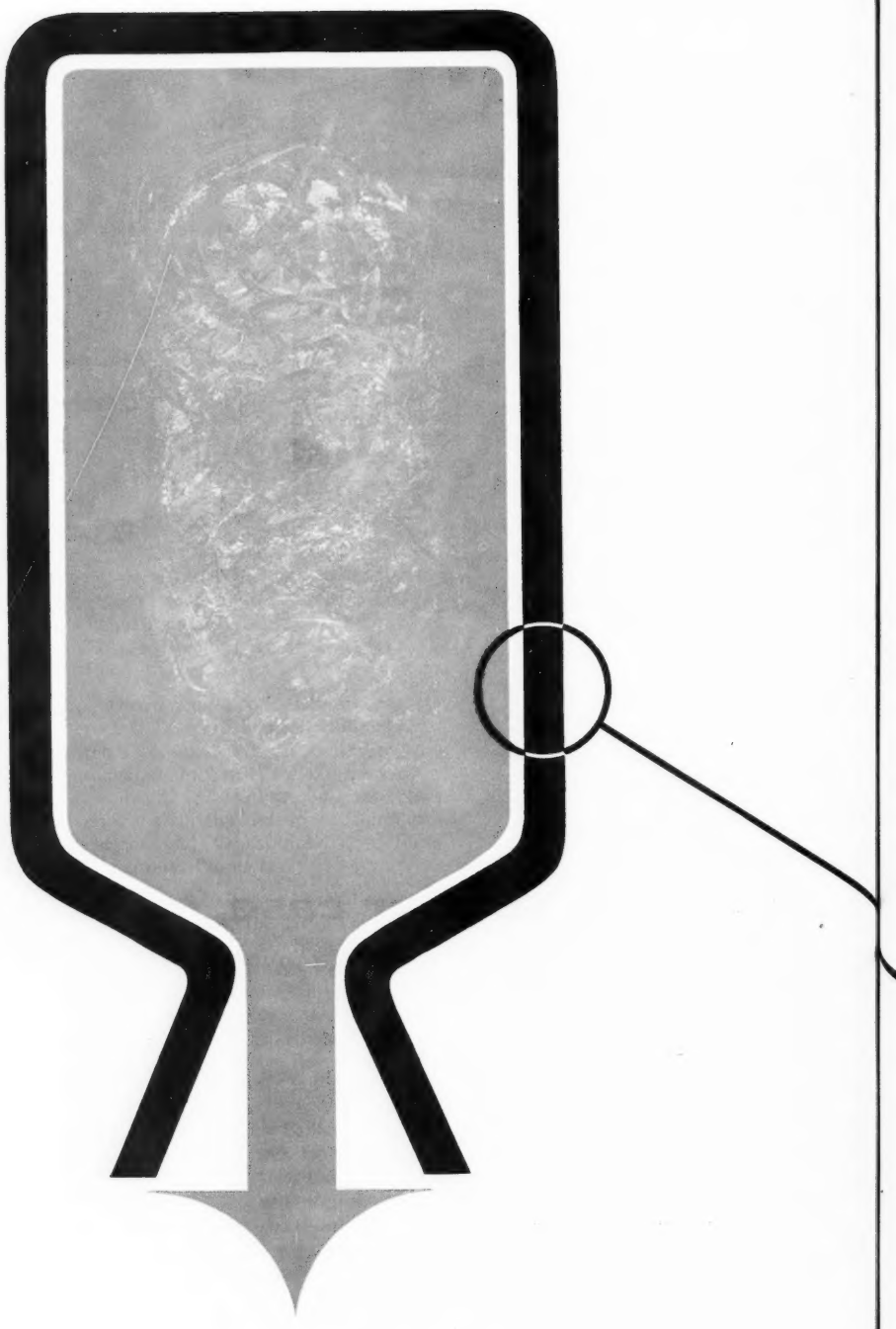


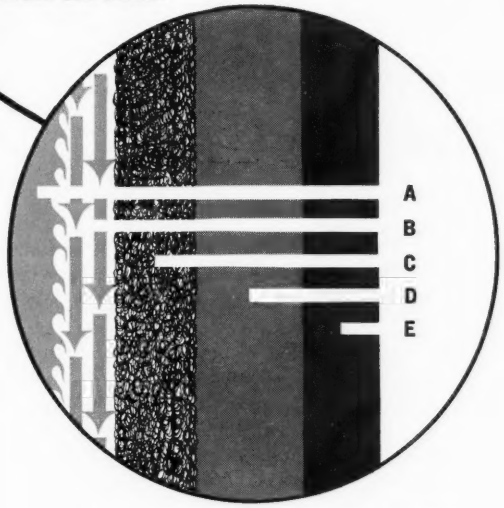
ASSIGNMENT:

Keep a raging rocket blast from destroying the case that holds it

How U. S. Rubber makes a missile fly further by putting a little salt on its tail

On the inside is the solid fuel. On the outside is the rocket motor case. And everything in-between is a problem.

Because the burning fuel goes as high as 6000° F, and the case itself can't take much more than 300° F, you've got to insulate one from the other.



A–Combustion B–Transpirational Cooling Film
C–Char Formation D–Virgin Insulator E–Rocket Case
Char alone reduces temperature approximately 2500°!

Yet weight and size are critically important, too. You want to use as little insulation as you possibly can. The less insulator weight, the further the missile will go, or the more payload it will carry. And the thinner the insulator, the more fuel you can pack in. Which again means more distance or payload.

The best insulator yet found is rubber. The rocket heat attacks the rubber to form a layer of char or ash that has a high insulating value. As this char is carried away by the rocket blast, new char is continuously being formed from the remaining rubber. Ideally, the entire insulator is used up at exactly the moment the fuel burns out.

There are ashes . . . and ashes

U. S. Rubber scientists have developed an insulator system that is at least twice as efficient as that previously used. It will enable solid fuel missiles to cut insulator thickness in half. To fly further. To carry more. It should even allow the use of still hotter fuels, if required.

The secret? Salt.

Drawing upon its unequalled experience in the development of chemical "blowing" agents for rubber and plastics, US has incorporated special chemical salts in its insulator compound to produce a simple, yet highly rewarding effect.

As the virgin insulator compound is attacked by the heat of the motor, it is automatically transformed into an open, sponge-like consistency just before it turns to char. The result is a "structured" char or ash with much superior insulating properties.

And that's not all. As gas is formed during this continuous, automatic "blowing" process, it passes through the layer of char to form an additional cooling film between the burning fuel and the char itself. Thus, with the creative application of experience and a known principle, U. S. Rubber has been able to double the effectiveness of rocket motor insulators.

Even at this writing, still further creative approaches to this whole general problem of "sacrificial" insulations are being explored, promising still further achievements in the days ahead. With one of industry's most advanced research and development organizations . . . with broad investigative and productive facilities in chemistry, rubber, textiles, and plastics, U. S. Rubber has had long experience in supplying America's defense establishment.

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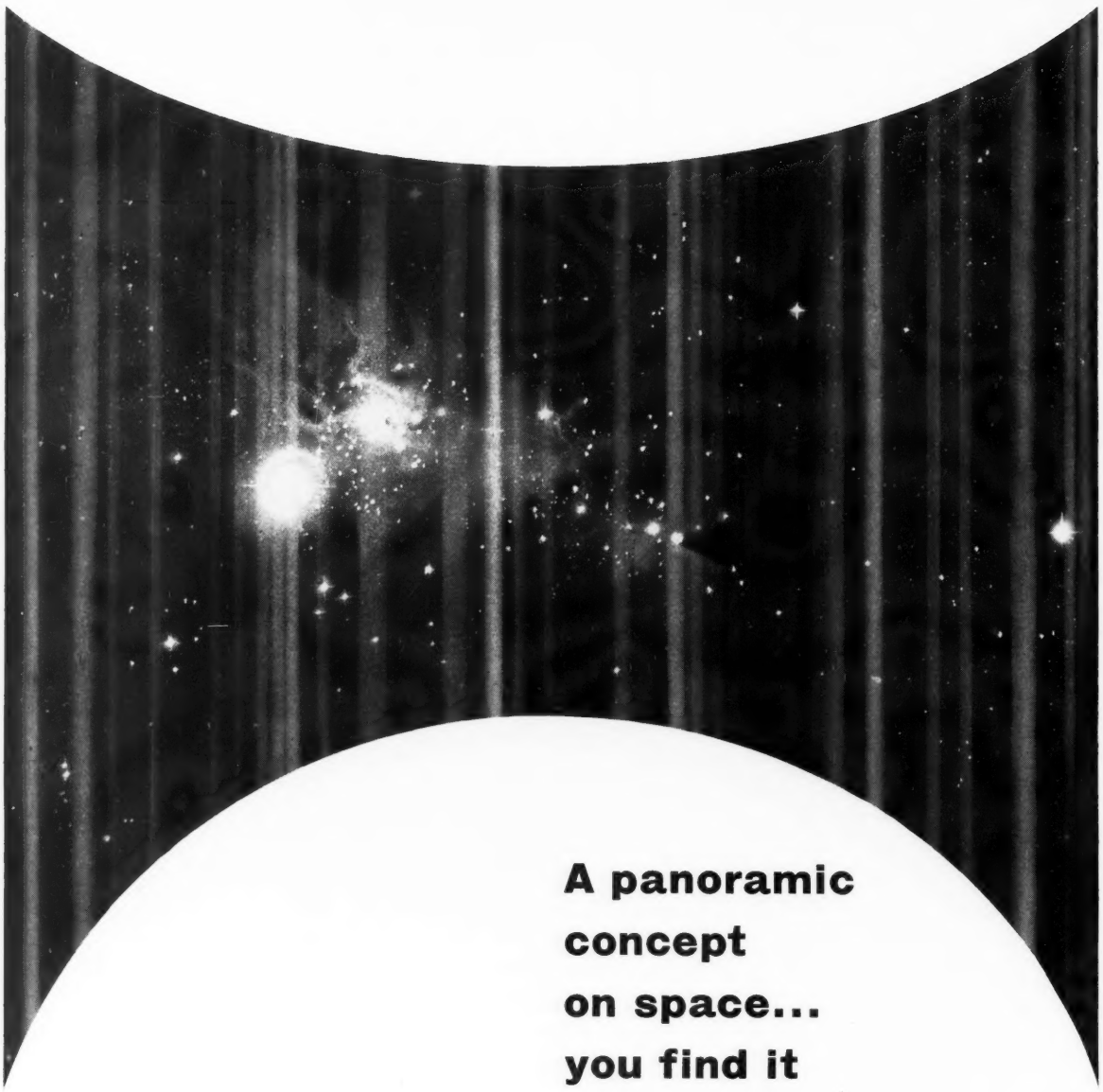

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This far-ahead program in the concepts and vehicles of space creates a climate most favorable to advancement in the state of the art as well as in professional status.

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Six Years

To summarize six years of association with the national affairs of the American Rocket Society, it seems appropriate to abandon the editorial chair in favor of the table.

	January 1, 1956		January 1, 1962 (Estimated)
Annual Dues	$15.00		$20.00
Members	3500		20,500
Sections	30		53
Student Chapters	0		45
Corporate Members	45		170
Publications	1		2+
Meetings		(Note 1)	
Full-time Staff		(Note 2)	
Financial Reserve	Small		Small (Note 3)
Technical Management		(Note 4)	
The Future		(Note 5)	

Notes:

(1) Before 1956, the ARS held most meetings jointly with other societies to insure adequate attendance. We now have approximately 12 annual, highly technical specialist conferences, and one general annual meeting—a real whing-ding—But don't we deserve it!

(2) We have always been blessed with a competent and dedicated permanent staff which has been able to rise to the constantly increasing challenge. Fortunately, the Society is now able to offer real career opportunities to its worthy full-time employees.

(3) The Society is a nonprofit institution. Its vitality is exemplified by the fact that there is always more to be done than there are financial means for the doing. Fortunately, we were born to be poor!

(4) Management of the technical affairs of the Society is vested in the members of its 19 technical committees, representative of the best talent in the world in each respective field. If there is a better way, we want to find it. But we are proud of this one.

(5) Ahead of us is what we perceive to be humanity's greatest challenge in the exploration of its environment. But may we always remain receptive to revolutionary ideas—avoiding a hierarchy of scientific conservatism—seeking ever better methods of communicating ways to live in a hostile environment which will yield only to the best combined efforts of our little pointed heads.

On behalf of all members of the ARS, it is an obligation to express our appreciation to our standing committees, technical committees, and permanent staff, all of whom have set a new high this year in dedication and personal effort. No organization is any better than its components, of which you are one.

Harold W. Ritchey
President, American Rocket Society

SPACE FLIGHT REPORT TO THE NATION OCT 9-15

SFRN hears call for full community participation to achieve space goals

With sweep and color, ARS Space Flight Report to the Nation set forth the swelling progress and urgent problems of the national space program . . . 12,811 professionals register . . . Public attendance runs well over 42,000

By John Newbauer

"THE space program is now distinctly a matter of public policy and politics. . . . We must do more to educate the American public." These words of New York Congressman William Fitts Ryan, member of the House Space Committee, at opening ceremonies of the ARS Space Flight Report to the Nation, struck a theme to be heard often at the meeting getting underway.

Before the week was out, it would be clear that the SFRN had become a rallying place to provide that "more"; had given a yardstick against which to measure efforts of the profession, government, and industry to act concertedly in the public interest; and had broken all records for space conferences.

The space fraternity came first, from across the country, more than 12,000 strong, to present results and to hammer at the potentially explosive engineering, scientific, and management problems that give the space program its heady quality. Over 42,000 curious

Columbus Circle, just in front of New York's Coliseum, during the SFRN.

1962 ARS Officers and Directors

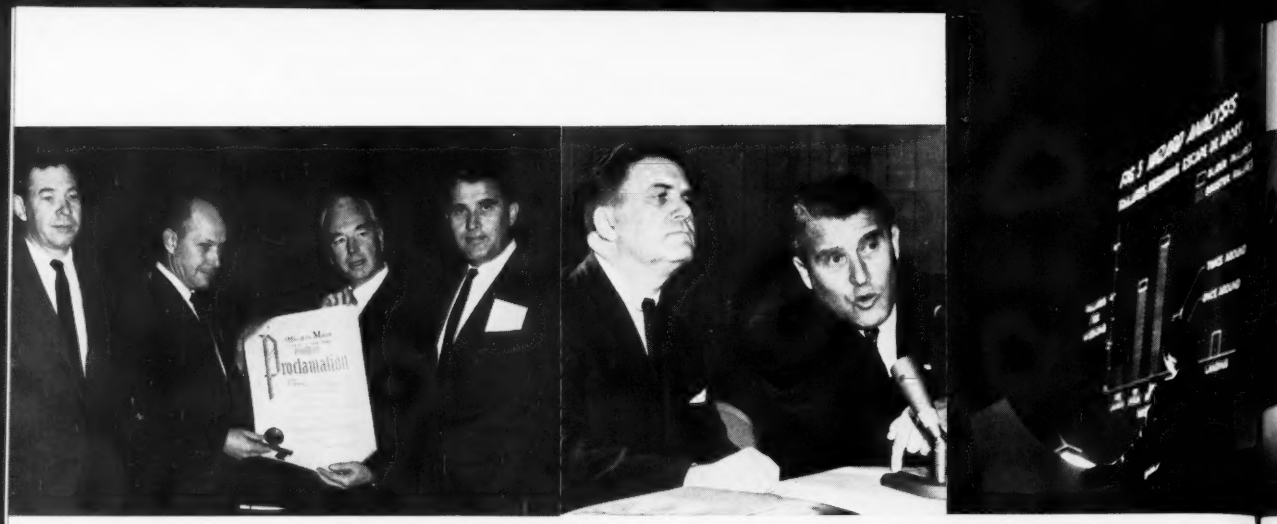
OFFICERS

President	William H. Pickering
Vice-President	Martin Summerfield
Executive Secretary	James J. Harford
Treasurer	Robert M. Lawrence
General Counsel	Andrew G. Haley
Director of Publications	Irwin Hersey

BOARD OF DIRECTORS
(Terms expire on dates indicated.)

Austin W. Betts	1964	Robert A. Gross	1962
Ali B. Cambel	1962	Samuel Herrick	1963
Richard B. Canright	1962	Arthur Kantrowitz	1963
William J. Cecka Jr.	1963	*Hilliard W. Paige	1964
*Bernhardt L. Dorman	1962	Simon Ramo	1963
Herbert Friedman	1962	†John L. Sloop	1964
†George Gerard	1964	*Ernst Stuhlinger	1964
		Abe M. Zarem	1963

* Newly elected. † Re-elected.



Left: The SFRN opens formally Monday morning as New York Commissioner Robert Watt, beside SFRN Chairman Wernher von Braun, presents ARS President Harold Ritchey a key to the City and a proclamation from the Mayor declaring October 9–15 "Space Flight Week." New York Congressman William Fitts Ryan, at left, member of the House Space Committee, prepares to give the opening address and sound a keynote of the meeting—the space program is now distinctly a matter of public policy and politics. Center: NASA Administrator James E. Webb and NASA-Marshall Director Wernher von Braun face the press and answer questions on rendezvous plans. Right, an indication of the polish to many technical sessions.

visitors joined them as the week progressed.

Against this panorama of the professional's work, a display of industry's products and plans in the Astronautical Exposition, and the public patronage, leaders in the space community addressed the profession and their fellow citizens.

Newly elected ARS President William H. Pickering, director of the Jet Propulsion Laboratory, set the stage in the first of a series of outstanding luncheon addresses: "Let us consider for a moment the statement of ARS purpose and objectives . . . to aid professional development, publish effective technical communications, grant awards and honors, aid education, and, finally, communicate to the nation at large." Outgoing ARS President Harold Ritchey, new Vice-President Martin Summerfield, and the ARS Directors (listed on page 21) joined him in this sentiment, and his audience seconded him with that sharp applause having the ring of authentic feeling.

How to act, how to be successful, how rightly and greatly to represent our national community, and indeed men the world over, in space? At luncheons, NASA Administrator James E. Webb, physicist and educator James Van Allen, AF Gen. Bernard A. Schriever, TRW Executive Vice-Presi-

The professionals and the public came and kept coming to what was described as the greatest technical display New York's Coliseum has yet witnessed; here, the main area of the second floor during a morning early in the week.

Over 700 members of the press attended the meeting to bring news to the technical community and public. Left, a corner of the busy press room. Center, NASA Associate Administrator Robert C. Seamans Jr., left, and Mrs. Seamans pause in front of Grumman's Orbiting Astrophysical Observatory mockup and chat with John Garelle, the company's representative to NASA on the OAO program, while viewing the Astronautical Exposition. Right, AFSC Commander, Gen. Bernard A. Schriever, and GD/Astronautics President James R. Dempsey exchange a word on the progress of the meeting.

dent Simon Ramo, and New York Senator Jacob K. Javits broached these questions on no easy terms. Excerpts from their talks appear on pages 26–27.

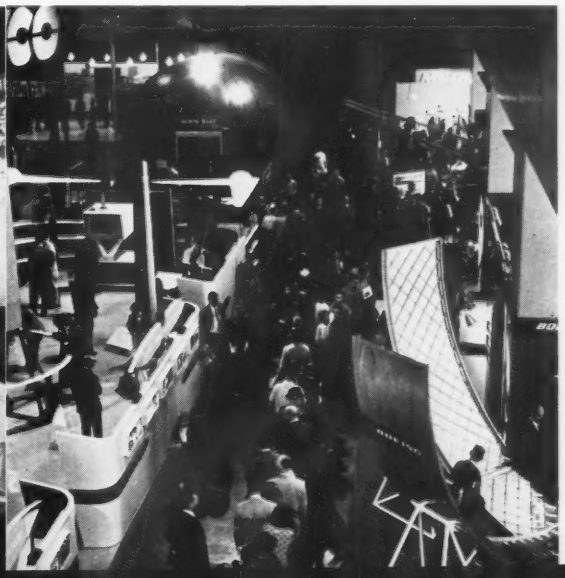
Against this background, Vice-President Lyndon B. Johnson, chairman of the National Space Council, came to voice a hope and challenge of today—space activities peaceful in intent and offering justice to all nations—as the featured speaker at SFRN Banquet Night. Some of the Vice-President's remarks appear on page 25.

Vice-President Johnson was not without the candor to comment that, "All too often, the government space installations are training grounds for the highly paid technicians and vice-presidents of private industry. We lose far too many of our best people," and thus plunge into a truly thorny political thicket of long standing.

It was with authority that Vice-President Johnson concluded his speech calling for unity and dedication in the national space program:

"If I could get but one message to you it would be simply this: The future of this country and the welfare of the free world depend upon our success in space. There is no room in this country for any but a fully cooperative, urgently motivated, all-out effort toward space leadership.

Left, the prospects of worldwide satellite communications begin with a talk to potential users. Right, a chance to visit the "moon" kept a steady line-up in this aisle.



"No one person, no one company, no one government agency has a monopoly on the competence, the missions, or the requirements for the space program. It is and it must continue to be a national job . . .

"As President Kennedy said just this week in regard to the space program: 'I will continue to be dissatisfied until the goal is reached. And, I hope everyone working on the program shares the same view.'

"I am confident I can bring back to him your full agreement with that determination."

By the time the Vice-President ("our best really big space booster," as he was termed by NASA Administrator Webb) rose Friday evening to give his address, which was aired coast-to-coast on radio, nearly 13,000 professionals had streamed into the Coliseum to hear over 200 papers and participate in numerous panels and informal get-togethers. The Astronautical Exposition was jammed with public visitors, as it would be Saturday, Education Day, and Sunday afternoon and evening. Honors had been bestowed on those who have contributed much to the space program, and paths to new accomplishments had been set before the profession.

ARS Awards Presented

Concerning honors, ARS Awards this year included:

- The Robert H. Goddard Memorial Award to Wernher von Braun, director of NASA's Marshall Space Flight Center, for his many contributions in rocketry and astronautics and for his untiring efforts to advance man's space capability.
- The ARS Propulsion Award to Robert B. Young, vice-president of Aerojet-General and manager of its liquid rocket plant, for his outstanding contributions in the field of liquid rocketry.
- The first ARS Research Award to James Van Allen, head of the Dept. of Physics at Iowa State Univ., for his contributions to basic research in astronautics and rocketry.
- The ARS James H. Wyld Award to Harrison A. Storms, president of North American's Space and Information Systems Div., for his outstanding leadership and distinguished engineering and administrative contributions to the X-15 program, constituting a major step in advancing the application of rocket power to manned space flight.
- The G. Edward Pendray award to Krafft Ehricke, director of Project Centaur at GD/Astronautics, for his outstanding contributions to the literature of rocketry and astronautics, as well as sharing of his creative thinking and knowledge before learned societies and university groups and his many original contributions that have informed and stimulated other space scientists and engineers.
- The ARS Undergraduate Student Award to Ronald H. Winston of Harvard Univ. and his associate Franklin J. Kosdon of MIT for their original paper on "Experimental Development of an Isocyanate Solid Propellant."
- The ARS Graduate Student Award to Bengt U. Sonnerup, recent doctorate winner at Cornell Univ., for his self-reliance, maturity of judgment, and contributions in the field of magnetogasdynamics.

Elected ARS Fellow Members at the meeting were these distinguished individuals of the space fraternity:

David Altman, vice-president of United Technology; Col. Jack L. Armstrong, USAF (Ret.), Nuclionics manager of Rocketdyne; Joseph V. Charyk, Under Secretary of the Air Force; Hugh Dryden, NASA deputy administrator; Alexander H. Flax, vice-president and technical director of Cornell's Aeronautical Laboratory; Robert Gilruth, director of NASA's Space Task Group; Karl L. Heimburg, director of NASA-Marshall's Test Div.; Maxwell W. Hunter, chief engineer, space systems, Douglas Aircraft; Maj. Gen. Don R. Ostrander, AFSC vice-commander; Robert J. Parks, JPL's chief of planetary programs; Ronald Smelt, director of XZ project, Lockheed Missiles and Space Co.; Rear Adm. Levering Smith, technical director of the Navy's Special Projects Office; Sidney Sternberg, chief engineer of RCA Astro-Electronics; Hubertus Strughold of the AF School of Aerospace Medicine; Martin Summerfield of Princeton Univ.; Adolf K. Thiel, vice-president of Space Technology Laboratories; Robertson Youngquist of the Institute of Defense Analyses; and William E. Zisch, vice-president and general manager of Aerojet General.

The Space Flight Report panels—on Vehicles, Missions, and Global Effects (see page 29); the

(CONTINUED ON PAGE 28)

The bread-and-butter work of the SFRN saw the professionals busy at technical sessions, left, and hitting the ARS preprint line, right.

Lyndon B. Johnson, Vice-President of the United States and Chairman of the National Space Council, takes the rostrum at the SFRN Banquet to discuss our "Challenge of Space," excerpts from which are given here.

Vice-President Johnson voices international space goals at SFRN Banquet . . .

"We want to make the space age an age of peace. We have no desire to convert outer space into a battleground of the cold war. We are thinking of peace, not conflict; of the hope that the gleam of a brighter future may yet fall from the reaches of outer space on our divided and quarrelsome earth.

* * *

"It is true, of course, that many of the scientific techniques used in civilian research can also be applied to military purposes, but there should be no confusion anywhere about the abiding principles of American policy.

"We are developing the peaceful uses of outer space from choice, but we are working on the military uses of outer space from necessity.

"That difference is basic, not superficial. It is genuine, and not artificial. And it is permanent and not temporary.

"There should be no obstacle to the establishment of international rules, preferably under the United Nations, for outer space. We renew our proposals to all members of the United Nations to join with us in making at least a brave start in dedicating outer space to the blessings of peace.

"We can expand the systems of control and cooperation as confidence in our mutual purposes steadily grows on the basis of experience. But we cannot wait indefinitely with impunity.

"Time presses, suspicions multiply, anxieties accumulate, and opportunities vanish. The necessity of an international agreement becomes more important, and more difficult, as our advances into outer space become bolder and more venturesome.

"It is the solemn hope of the American government that all nations will recognize this new opportunity for peace . . . ."

The head table at the SFRN Banquet reflects a vigorous and growing ARS.

Leaders in space community bring tough

William H. Pickering, Director of the Jet Propulsion Laboratory and newly elected ARS President—from "Space, Professional Societies, and the National Interests."

"Our membership encompasses the entire missile and space business of the country. At this disturbing moment in history, the future of our nation, indeed of the whole civilized world, depends to a large extent on the skill and ingenuity of you, members of ARS.

"As we begin this ARS Space Flight Report to the Nation, against the background of Russian and American space flights of the past four years, and the President's message to the Nation this spring, I know I can say to him on behalf of our Society, and each of you individually: Mr. President, we in the American Rocket Society welcome your program for the conquest of space. We believe in it. We know it can be done. We pledge you our help in every way possible."

James Van Allen, Head of the Physics Dept., State University of Iowa—from "The University's Space Role."

"We witness today what I regard as 'the great chasm' in our space program. . . Our national ambitions have greatly outrun our national competence. We can doubtless continue to muddle along in this style in a more or less creditable way for a while—especially since our international competition suffers from the same malady. But in due course, our efforts will become less and less imaginative and resourceful and more and more pedestrian—even though technically proficient in the limited sense. The idealized role of the universities is then to put the fine cutting edge on the massive and relatively blunt intellectual tools which we are using.

"Only if universities are full-fledged partners in the national space effort can we develop the broad-gage, long-term competence which the public and the Congress so ardently expect."

James E. Webb, NASA Administrator—from "Our Expanding National Space Program."

"On policies ARS follows, on your drive and effectiveness, rests much of what the nation will do to lift from the realm of dreams to the area of practical things the goal of manned interplanetary travel that your founders envisioned in 1930.

"With respect to the utilization of solid or liquid propellants in our largest boosters, we are carrying out development of both for such a period as is required to make the necessary evaluation.

"With respect to the possibility—for our most advanced missions—of building a large spaceship out of components placed in orbit around the earth by medium-sized rockets, as against the advantages of using a giant-sized booster of the Nova class, we are proceeding with the necessary fact-finding. We are incorporating into our decisions on programs and facilities the flexibility that will permit us to take advantage of either these or other proposed methods for accomplishing our goals."

national issues before luncheon audiences . . .

Gen. Bernard A. Schriever, Commander, U.S. Air Force Systems Command—from "Space and National Security."

"The key to rapid utilization of space by man for military purposes is flexibility. We must not design our space vehicles and programs just to achieve those objectives which we can define now. We must design the vehicles with enough capacity to rapidly adapt to or incorporate knowledge which will flow from our space program. . . .

"This, then, is what we need; but if we are going to achieve our national goals in time, we may have to rethink our traditional approach to the use of technology. Historically, we have tended to overestimate what we could do on a short-term basis, and to underestimate grossly what we could do on a long-term basis. As a result, the U.S. has been notably slow to recognize the military application of new inventions. This was an adequate philosophy for the days when oceans were real barriers and gave us time to mobilize after war's outbreak. Today, technological surprise could be fatal."

Simon Ramo, Executive Vice-President, Thompson Ramo Wooldridge Inc.—from "A Proposal for a New Industry-Government Relationship on Developmental Programs."

"No one doubts that we are engaged in a massive transition to a new highly technological society.

"Industry-government relations for joint effort on major developmental projects today are such as to constitute one of the major bottlenecks in the speed of technological progress in the U.S. Competition and profit incentives are not being used to the fullest, and, in fact, are at work largely for the acquisition of new work rather than for the performance of work already committed to.

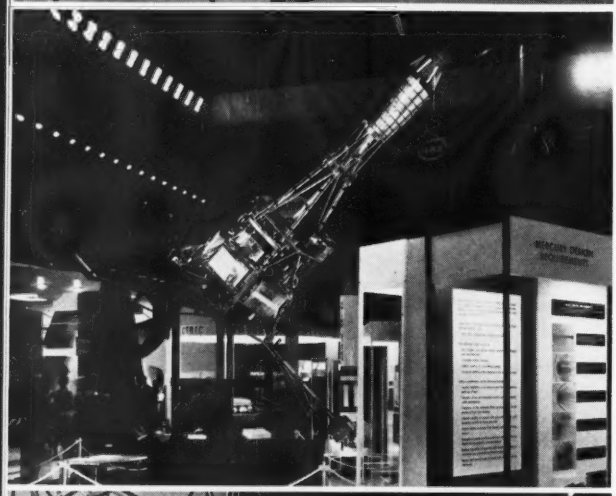
"It is deemed essential that some major modification be made in the system so that performance will be more influential in both award and reward. This is possible if a major effort is given to the planning and implementation of a formal organization that has performance rating as its special permanent role. . . ."

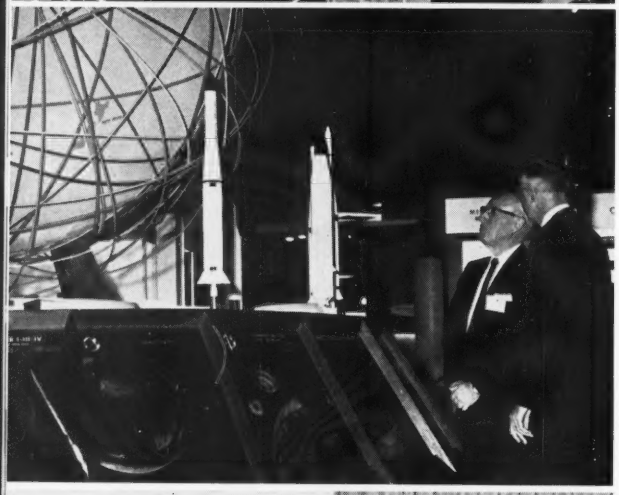
Sen. Jacob K. Javits (R., N.Y.)—from "Education and Law in the Space Age."

"The launching of Sputnik in 1957 by the USSR marked the beginning of a historic demand for a more effective and modern educational system in the U.S. But in the three years since, this has not been fully realized in legislation.

"We find overcrowded classrooms, inadequate teaching staffs, and outmoded equipment—the picture is not good. Our great nation is not maintaining an educational system of the quality of which we are capable; and we are wasting the talent and energy of thousands of Americans who should have been educated at higher levels of skills and knowledge. I can think of no failure of our society quite as tragic as this one.

"The enactment of Federal aid to education bills is the greatest immediate contribution we can make to catching up in the space age. . . ."





unusual Thursday evening program on "The U.S. and USSR Space Programs: A Critical Evaluation," which was open to the public and received extensive press attention; an evening devoted to discussion and films on the evolution of American liquid-propellant engines; technical panels on electrical propulsion, the launch-operations challenge, communication satellites, satellite design, the national space-power systems program, and advanced guidance; an extensive National Aeronautics and Space Administration Program Report; and other sessions and special topics too numerous to mention—combined to give an unprecedented picture of the genesis of our space program, its successes and problems, and its most likely future paths and shapes.

Much of what emerged from these sessions has now appeared in headlines and in the technical press, but a few words summarizing major topics may be appropriate:

Rendezvous: A decision will be made by the end of this month, according to NASA Chief Webb, on whether to use Saturn C-3 or C-4 to rendezvous 400,000 lb of payload for a manned lunar mission. Studies by the NASA-DOD rendezvous committee headed by N. Golovin suggest this technique will save program time and costs and will ease the launch-operations problem in some ways. The study of Nova-class boosters will continue, and the Nova capability will remain a goal of the space program.

Launch Operations: Launch operations do not keep pace with mission requirements. They will have to be changed. Automatic checkout of vehicle modules and subsystems has certain drawbacks and will have to be carefully investigated. NASA-Marshall SFC has designed a broadly simplified launch complex for large Saturn vehicles (as described by

(CONTINUED ON PAGE 32)

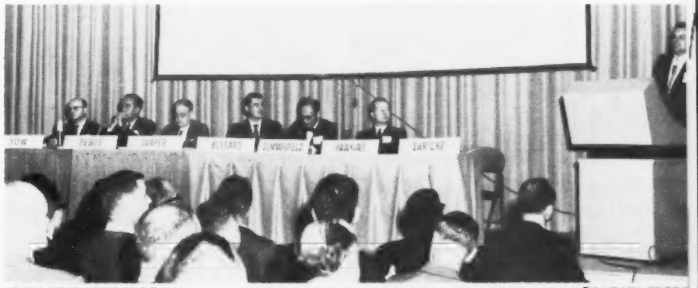
Missions, vehicles, global effects, Russian vs. American programs—each figured prominently in the SFRN Astronautical Exposition and special technical sessions. At top, the promise of nuclear power stands high in future missions, as depicted in the NASA-DOD exhibit; a working prototype of JPL's Ranger spacecraft shows the new forms space will give vehicles; Congressman George P. Miller (D., Calif.), chairman of the House Space Committee, who gave a paper on "Policy Problems of Communication Satellites," looks at the already satellite-entwined globe in the NASA exhibit; and, bottom, Leo Steg of GE's Missile and Space Vehicle Dept. opens a Space Education Day session on undergraduate education in the space-flight era —an important facet of international competition—with participating panelists, from right, Paul Sandorff of MIT's Dept. of Aeronautics and Astronautics, Paul Chenea, vice-president for academic affairs of Purdue Univ., and Loren Morey, propulsion specialist of Hercules Powder's Magna, Utah, facility.

THE U.S. AND USSR SPACE PROGRAMS: Moderator Arthur C. Clarke, past chairman of the British Interplanetary Society, at far left, introduces his Space Flight Report Panel on the Space Programs: From his left, Hugh L. Dryden, NASA deputy administrator; Gen. B. A. Schriever, head of the Air Force Systems Command; F. J. Krieger of Rand Corp.; Arthur R. Kantrowitz, vice-president of Avco Corp. and director of Avco-Everett; and Wernher von Braun, NASA-Marshall director.

Space Flight Report panels draw thousands from the professional community . . .

Over 1000 of the professional space community attended each of the three special afternoon Space Flight Report panels shown below, and a mixed audience of professionals and public numbering upwards of 2400 gathered Thursday evening to hear panel above evaluate U.S.–USSR space programs.

Highlights of these occasions included NASA Deputy Director Hugh Dryden's cool fielding of several loaded policy questions and his shrewd judgment of Russian space progress; NASA Director of Launch Operations Kurt Debus' timely description of advanced launch techniques and facilities for very large space vehicles; and the brilliant exposition by Cornell Univ.'s Philip Morrison on the likelihood of higher life forms in our galaxy, and the challenge this will soon put before the scientific community and society at large. Professor Morrison received the biggest hand of the panel sessions.



THE VEHICLES: Moderator Krafft Ehricke, Centaur director for GD/Astronautics, introduces SFR Panel on Vehicles: From right, Willis M. Hawkins, vice-president and general manager of Lockheed Missiles and Space Co.; Martin Summerfield of Princeton Univ.; R. W. Bussard of the Nuclear Propulsion Div., LASL; C. Stark Draper, head of MIT's Dept. of Aeronautics and Astronautics; Kurt H. Debus, director of Launch Operations Directorate, NASA-Marshall; and Norris F. Dow of GE's Space Sciences Lab.

THE MISSIONS: Moderator Arthur R. Kantrowitz, director of Avco-Everett, introduces SFR Panel on Missions: From right, Herbert Friedman, superintendent of NRL's Astrophysics and Atmosphere Div.; William H. Pickering, JPL director; F. W. Reichelderfer, head of the U.S. Weather Bureau; John R. Pierce, director of research for Bell Labs; and Robert R. Gilruth, director of NASA's Space Task Group.

THE GLOBAL EFFECTS: Moderator James H. Doolittle, chairman of the board of STL, introduces his SFR Panel on Global Effects: From right, Trevor Gardner, president of Hycon; Oskar Morgenstern of Princeton Univ.; Donald Mitchell, vice-chairman of the board of General Telephone and Electronics; Tunis A. M. Craven, FCC Commissioner; and Philip Morrison of Cornell Univ.'s Laboratory for Nuclear Studies.

Eighteen national space leaders became ARS Fellow Members in a luncheon ceremony the day of the SFRN Banquet. Samuel K. Hoffman, president of Rocketdyne, standing at the dais, did the honors. The new ARS Fellows include, left to right—David Altman, vice-president for research of United Technology Corp.; Col. Jack L. Armstrong, (AF, Ret.), previously with the AEC and now manager of Rocketdyne's new Nuclionics group; Hugh Dryden, NASA deputy administrator; Alexander H. Flax, vice-president and technical director of Cornell Aeronautical Laboratory; Robert Gilruth, director of the NASA Space Task Group; Maxwell W. Hunter, chief engineer, space systems, Douglas Missile and Space Div. Maj. Gen. Don R. Ostrander, AFSC vice-commander, Headquarters; (Dr. Ritchey and Dr. Ramo, who spoke at the luncheon, and Richard Canright and ARS Counsel Andrew Haley, taking part in other cere-

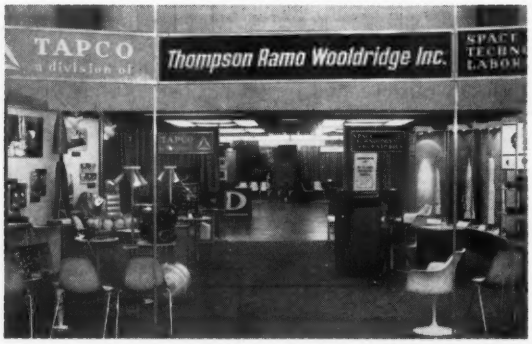
Space pioneer Hermann Oberth, who has lived to see many men share his world of ideas, watches a Space Flight Report in the company of NASA-Marshall's Ernst Stuhlinger, left, and writer on spaceflight, Willey Ley, right.

The Society honors those who create. From left to right, in the photos across this spread, outstanding contributors to the nation's missile and space programs receive ARS awards for 1961. Robert B. Young (right), vice-president of Aerojet-General and manager of the firm's Liquid Rocket Plant in Sacramento, accepts the ARS Propulsion Award from Richard Canright of NASA . . . James Van Allen (left) of radiation-belt fame receives the first ARS Research Award and an accompanying $2500 honorarium from Donald Douglas, whose company sponsors the new award . . . Mrs. James H. Wyld presents the ARS James H. Wyld Award to Harrison A. Storms, now president of North American Aviation's Space and Information Systems Div., for "his outstanding leadership and distinguished engineering and administrative contributions to the X-15 program, constituting a major step in advancing the application of rocket power to manned space flight" . . . Krafft Ehricke (right), Centaur program director for GD/Astronautics, receives the G. Edward Pendray Award from its donor for his many stimulating contributions to space-flight litera-

monies); Robert J. Parks, chief of Planetary Programs for JPL; Ronald Smelt, director of XZ Project, Lockheed Missiles and Space Co.; Sidney Sternberg, chief engineer of Astro-Electronics Div., RCA; Hubertus Strughold, adviser for research of the USAF School of Aviation Medicine; Martin Summerfield, professor of aerospace propulsion at Princeton Univ.; Adolf K. Thiel, vice-president of STL's Systems Programs Management; Robertson Youngquist of the technical staff, Institute of Defense Analyses; and William E. Zisch, vice-president and general manager of Aerojet-General. New Fellow Members Karl L. Heimburg, director of NASA-Marshall's Test Div., Rear Adm. Levering Smith, technical director of Special Projects Office, Navy Bureau of Ordnance, and Joseph V. Charyk, Under Secretary of the Air Force, could not be present at the luncheon.

Mrs. Robert H. Goddard presents Wernher von Braun with the Robert H. Goddard Memorial Award for "his many contributions in rocketry and astronautics and for his untiring efforts to advance man's space capability. . ."

ture and for untiring efforts to spur professional groups to creative thinking on space problems . . . Bengt U. Sonnerup (right), a recent doctorate winner from Cornell Univ., receives the ARS Graduate Student Award with a $1000 honorarium from ARS President Harold Ritchey, representing his company, Thiokol Chemical, which sponsors the award. Sonnerup, of Malmo, Sweden, was cited for his "self-reliance, his maturity of judgment, and his contributions in the field of magnetogasdynamics" . . . Franklin J. Kosdon of MIT (left) and beside him associate Ronald H. Winston of Harvard Univ. accept the ARS Undergraduate Student Award and an equal share of its $1000 prize, sponsored by the Chrysler Corp., from Chrysler's Washington representative John Cannon. The two university juniors submitted a winning paper on "Experimental Development of an Isocyanate Solid Propellant." In the foreground, Purdue's Maurice J. Zucrow . . . At the luncheon, ARS General Counsel Andrew G. Haley announced that the ARS Astronautics Award, which he sponsors, will be awarded to Astronaut Alan B. Shepard.



The SFRN Astronautical Exposition's "exhibiting in depth"—a fancy phrase for putting some room in the aisles and urging companies to hold the viewers' attention by spanning areas with exhibits—proved a welcome relief from

Kurt Debus in a model presentation at the Vehicles Panel). Some company and military representatives still do not understand the importance of this work. Launch operations suffer from "standpatism." An audience of over 600 could find few questions to ask about this tough subject.

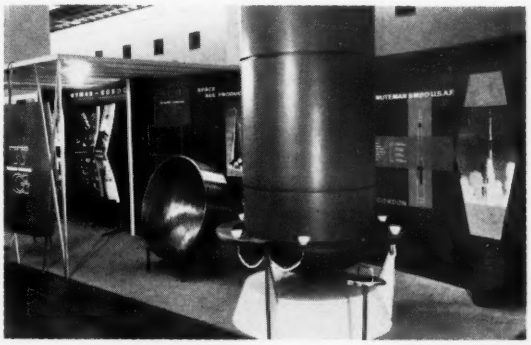
Nuclear Rockets: The space-vehicle designers can scarcely wait to get their hands on a solid-core nuclear rocket. Kiwi-B will answer the technical questions for operational design (Nerva). Ground handling and flight safety will pace the operational use of Nerva. The Mars mission study is a serious one now in advanced-planning groups.

Manned Orbital Laboratories: There will be an expanded effort on manned orbital laboratories. The Air Force has moved to take part in manned-laboratory operations. Boilerplate models of such laboratories will be launched by 1964. They will provide one means of testing rendezvous techniques.

Spacesuits: No one is very happy with present spacesuits. They are tricky and clumsy. Suit design will require great attention and many advances for

The meeting featured three fine sessions on the environment of space. These scientists contributed to one—from right, J. Ruina (chairman), T. Gold, C. Sagan, W. W. Kellogg, G. J. F. MacDonald, and C. P. Sonett.

ARS Section management received attention from this panel. Its chairman, ARS Director Bill Cecka, left, chairman of the ARS Section Activities Committee, addresses the audience of Section delegates.



the run-of-the-mill trade-show practice. These photos indicate approaches of many exhibitors—open, plaza-like areas; aisle-running displays and pavilion-like booths; and more-conventional booths with greater space than usual.

operations outside space vehicles. The suit puts a clamp on some of the more ambitious mission ideas.

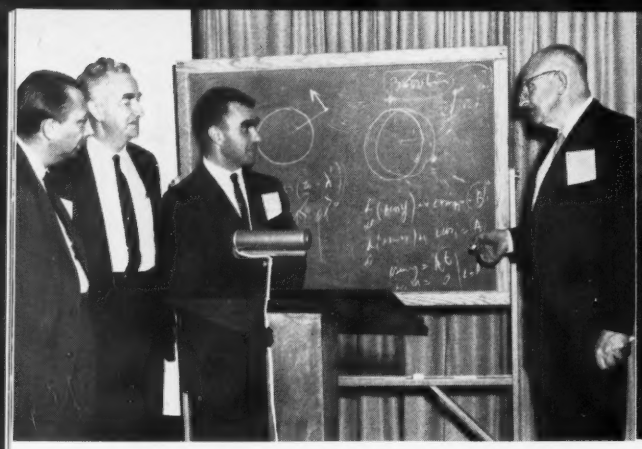
Electronic Space Equipment: A whole cycle of development and testing must be experienced before statements about the reliability and design predictability of electronic equipment in space acquires soundness.

Power Systems: Nuclear reactors for generating between 100 kw and 10 mw for space vehicles will at last become actively pushed as developments. The 300-kw Spur program was said to be complete as a paper study. Solar-cell arrays will continue to be a major prop in power systems. A figure of 7–9 watt per lb with converter was cited for the Nimbus solar-cell system. Transit will test a new and larger thermoelectric power system. Small solar mirrors show good performance, and mirrors up to 50 ft-diam can be expected as developments soon. Solid engineering development work lags throughout the advanced-power-systems area.

Electrical Propulsion: The electrical propulsion exponents show a new confidence in engineering of

This panel just barely caught NASA's W. A. Fleming's ball—the launch operations challenge. From left, R. L. Clark of NASA, Maj. W. Flint of AFMTC, N. Chase of Lockheed, A. Gooze of Aerojet, R. Gloor of STL, and Fleming. To rear, Col. P. B. Peabody, not on panel.

Graduate-student educational problems were tackled by these experienced members of the space community on Education Day. From left, session chairman G. W. Sutton of GE-MSVD, L. Kavanau of DOD, R. L. Bisplinghoff of MIT, and R. Horner of Northrop.



Astrodynamists, from left, Szebehely, Herrick, Leitmam, and Brower consider the space paths.

Vice-President and Mrs. Johnson, Dr. Ritchey, and Dr. Pickering turn for the camera at Banquet Night.

ARS staff members and Aerojet's Tom Sprague, second from right, handle stream of calls (for help).

Fred Whipple, center foreground, and Herbert Friedman, just off his hand, to rear, explain new space data to reporters.

Same old story—This is coffee?

their wide range of devices. They will push power-systems development, which paces application of electrical engines. *Fast* manned missions to the near planets appear possible with advanced electrical-propulsion schemes.

Lunar Operations: A manned shuttle from a lunar orbiter to the moon's surface and back to rendezvous is being given serious consideration. This would take the pressure off an astronaut-controlled launch from the moon. Automatic moon landing acquires even greater emphasis. The time approaches for giving Prospector specifications—vehicle and operations.

The Space Flight Report panels proper generated so many worthy observations that they will be the subject of a book to be published in the future. It is not possible to do justice to them or to the U.S. and USSR program-evaluation panel in a few words. The participants in these panels are pictured on page 29. About 2500 people heard the U.S.–USSR panel discussion, and few left until the last shot was fired.

The panels were informative and entertaining, especially when the partisan spirit began to flow. For instance, it was fun to hear Herbert Friedman say, "Thank God for the Aerobee rocket." And it sent your hair up to hear Phillip Morrison of Cornell Univ. describe the rational reasons to expect a high order of extraterrestrial life, and declare, "Show us one example of life outside the earth—then, up will go the big dishes!" Professor Morrison received a tremendous ovation for his talk.

In the U.S.–USSR panel discussion (see page 29), Dr. Dryden of NASA provided the pivotal comments and showed admirable coolness in handling a number of loaded questions.

Concerning Russian work, Dr. Dryden said that he gathers from his conversations with the Russians, and what anyone would find from the literature, that the USSR has produced no successful space-science payload since Sputnik III, and that Russian space scientists are a very unhappy group as a con-

The pros, the public, and officialdom gave and received at the most ambitious meeting yet undertaken by the space community. At far right, J. H. Browne, left, representing the Boy Scouts of America, presents Dr. Ritchey a token of appreciation for the contribution ARS has made to Boy Scout programs these past three years.

sequence. Dr. Van Allen commented in a similar vein at the meeting. According to what Dr. Dryden has heard, there are opponents of manned space flight in Russia.

Wernher von Braun, on the same panel, said he asked a prominent Russian scientist how they evaluated proposals in the USSR. The answer was, "Very unfortunately for us, we don't have good competitive bidding among informed groups." It is Dr. von Braun's belief that the Russians stick to well-known practice.

At the conclusion of this program, Dr. Dryden stressed the need to build understanding and support of the quickly growing space program. Dr. von Braun urged sustained effort over the coming decade.

After technical sessions, after panels, after honors and festivities, while the crowds milled through the Astronautical Exposition, came Education Day, Saturday. Four sessions then and one earlier in the week dealt with educational problems confronting the public, government, industry, university, young student, graduate student, and professional hoping to further his goals. Despite interesting presentations, Education Day did not hold the professional audience, and its aims will have to be recomposed and further forums for its ideas sought.

Informing Public a Major Goal

Aside from problems of formal education, Edward Welsh, executive secretary of the National Space Council, stressed the need for more and better attempts to inform the public on science and space technology. You can scarcely help thinking of the potential for doing this on television—a giant with toys in its hands. In one great metropolitan area, television, all of it, offers only a superficial and sporadic exposition of contemporary science and technology. Then, there is the public issue presented by Sen. Jacob Javits, featured speaker on Education Day (see page 27).

The Society and its supporters can be proud of acting while others worried about public education. Thousands of people could see part of the story of space flight, could build a personal experience and enthusiasm for the space program in the Astronautical Exposition. This experience can be extended through educational institutions at large.

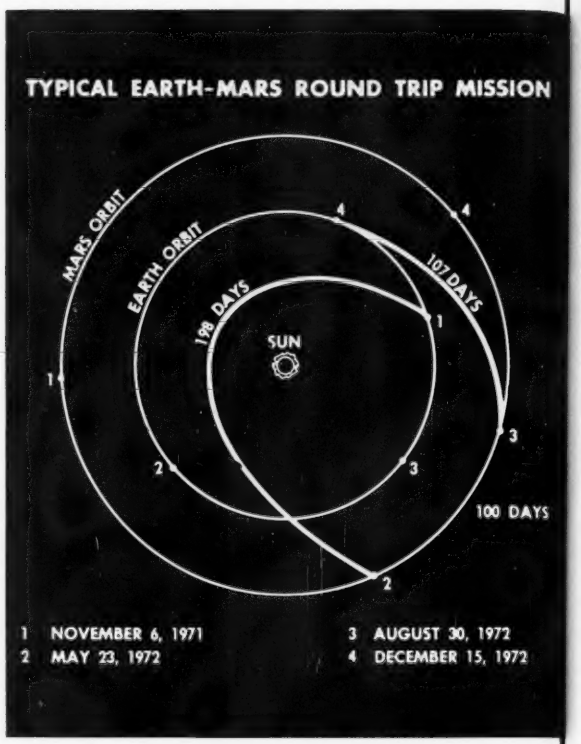
The professional who came to the ARS Space Flight Report to the Nation could scarcely miss enjoying an education. As ARS President-Elect William Pickering rightly said, "More can be learned here in a few days than could otherwise be done in months." ♦♦

End of a meeting—continuity and a new beginning.

STATE OF THE ART–1961

Astrodynamics

BY ROBERT M. L. BAKER, JR.
UNIVERSITY OF CALIFORNIA AT LOS ANGELES
CHAIRMAN, ARS ASTRODYNAMICS COMMITTEE



THIS year has seen a continuing acceleration in astrodynamic research and a consequent redoubling of the literature. A few more of the "old hands" of celestial mechanics have become more active in the field of astrodynamics, that is, in the practical application of celestial mechanics to astronautics; and, of course, there is the steady influx of newcomers to the field. It is a very healthy sign that an ever-increasing number of these newcomers are seeking postgraduate and even postdoctoral formal education in astrodynamics. Only through formal education taken hand-in-hand with practical ex-

STATE OF THE ART–1961

Communications and Instrumentation

BY FRANK W. LEHAN
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CHAIRMAN, ARS COMMUNICATIONS AND INSTRUMENTATION COMMITTEE

THE year 1961 saw a number of technical feats and developments that exemplify the considerable advances made in the state of the art of communications and instrumentation.

Venus Radar Bounce Experiment. This operation, performed again in the past year, was singularly significant in that it represented positive contact with another planet in our solar system. Further, it provided a considerable refinement in the accuracy of the Astronomical Unit, and was accomplished with a communications system composed of many elements which crowd the state of the art in performance. Two-hundred hours of valid recorded data resulted from the Venus-bounce experiment. Two months spent in reducing these data resulted in a figure for the A.U. of 149,598,500 plus or minus 500 km. There is every reason to believe that further data reduction and analysis

perience can the astrodynamic competence of our nation's scientific community be improved.

It is also heartening to see fewer research papers having limited distribution within specific companies or organizations. By and large, astrodynamic research is of an unclassified nature, and it is incumbent upon the researcher to see that his ideas are viewed by his scientific colleagues. Such publications not only expose them to the light of public scrutiny and criticism, but allow others to build up their work.

We are no longer in the era of the alchemist who secretly advanced the cause of science. For an individual or a group to carry out worthwhile astrodynamic activity (both theoretical and applied) it is mandatory that they allow their work to be observed by their scientific colleagues, even if the time expended in this pursuit may seem wasted. There have been all too many examples of national programs being executed by newcomers to astrodynamics who have neither benefited from formal education in the field nor published their research —all to the detriment of the program for which they were responsible. Often they have been frightened "to let others see," for fear of losing a hard-won government contract because of adverse criticism. Fortunately, such barriers to progress are gradually dissolving due in no small way to the increasing competence and astrodynamic education of Army, Navy, and Air Force officers and NASA officials who have discretion in the award of such contracts and who monitor the contract once it has been let.

New Texts Helpful

Representative of the interest of the celestial mechanician in the relatively new field of astrodynamics are the two new texts in celestial mechanics published in the past twelve months. The first was Theodore Sterne's "An Introduction to Celestial Mechanics" (Interscience Publishers, $4.50) and the second was Dirk Brouwer and G. M. Clemence's "Methods of Celestial Mechanics" (Academic Press, $12.50). Although both these books deal mainly with celestial mechanics, they have enjoyed a wide circulation among astrodynamists and are recommended reading for anyone seriously interested in the field. Another fine book related to astrodynamics is I. Berman's "The Physical Principals of Astronautics" (John Wiley & Sons, $10.50). Soon to be published will be (CONTINUED ON PAGE 80)

will reduce this uncertainty to plus or minus 150 km by the end of 1961.

The experiment provided other valuable information on Venus: It is either a highly specular reflector or it rotates at an extremely slow rate. Venus is a much better radio reflector than the moon.

Deep-Space Instrumentation Facility in Full Operation. The NASA's DSIF was completed in the past year and was demonstrated to have full operational capability. This achievement is significant because it provides this country with the capability to control and receive data from lunar and planetary spacecraft planned for the future. Successful operation of the DSIF worldwide net represents, further, an outstanding example of international cooperation, inasmuch as the Woomera and South African stations are operated by technical agencies of the Australian and South African governments.

High-Efficiency Communication Systems. The past year has seen considerable activity advancing the state of the art in the theory and mechanization of high-efficiency telecommunication systems of several kinds. Advances have been made in the areas of synchronization (CONTINUED ON PAGE 104)

Communication satellites, such as this developmental model being worked on by Bell Telephone Labs technicians, represented a focus for the state of the art of both communications and instrumentation last year. At least three different experimental communication satellites will be launched next year.

STATE OF THE ART–1961

Electric Propulsion

BY ERNST STUHLINGER
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NASA MARSHALL SPACE FLIGHT CENTER
SECRETARY, ARS ELECTRIC PROPULSION COMMITTEE

One year ago, *Astronautics* published several papers which described the status of electrostatic propulsion development.[1] Here we will report on the progress made during this past year and on program plans for the immediate future in the entire field of electric propulsion.

Three distinct classes of electric engines for space propulsion may be distinguished—electrothermal, or arc-jet, engines; electrostatic, or ion, engines; and electromagnetic, or plasma, engines.

Electrothermal propulsion utilizes an electric arc to heat the propellant, which is then ejected through a nozzle as in a conventional rocket. Because of their basic simplicity and their prior uses in other fields, arc jets passed rapidly through the phases of basic research and demonstration of feasibility. They are now in a relatively advanced state of development, although further improvements in power efficiency and lifetime are very desirable.

Electrostatic propulsion is based upon the accel-

STATE OF THE ART–1961

Guidance and Control

BY JAMES S. FARRIOR
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CHAIRMAN, ARS GUIDANCE AND CONTROL COMMITTEE

In considering the state of the art, it is helpful to take a brief look at how we got where we are today. Nearly all of the technology associated with today's guidance and control field has been developed during the past 25 years. The engineers and scientists associated with the field in its initial phases had the task of determining what physical principles could be applied and of devising devices and systems which would exploit these principles. Thus the gyroscope, the pendulous integrating gyro-accelerometer, the pendulous torque-balance accelerometer, the double-integrating reaction-motor accelerometer, gimbal systems, Doppler devices, etc., as well as various types of computing elements, all came into being during the early phases.

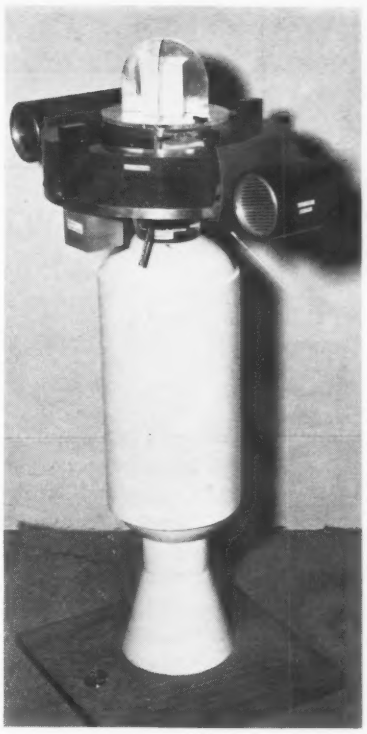
However, it has been an extremely difficult task to go from the initial conceptions to today's high-quality devices. It has been necessary to perfect new materials, new manufacturing techniques, and new analytical techniques, as well as to come up with a few basic inventions.

Almost any guidance and control engineer today can analyze and design a rather complicated servo or other feedback device, and it is hard to realize

eration and ejection of charged particles by purely electrostatic fields. After considerable progress during the past year, ion propulsion is now beyond the feasibility-demonstration stage, but continued research and component development in some areas will be necessary for the successful development of useful space propulsion devices.

Acceleration of the propellant in electromagnetic propulsion systems is achieved through the interaction of stationary or varying magnetic and electric fields with an ionized plasma. Electromagnetic propulsion has required a great deal of basic research and technological advancement. It entered the feasibility-demonstration stage only recently.

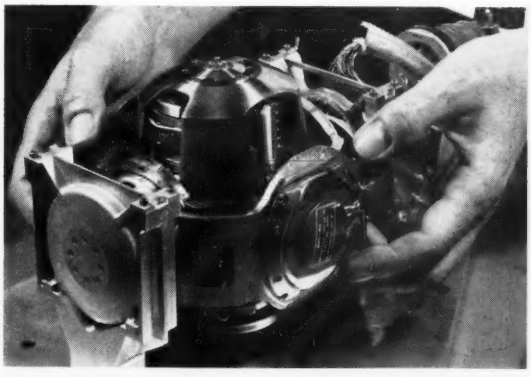
Arc-Jet Engines. Arc-jet engines consist of propellant storage tank, flow-control system, arc thrustor with nozzle, and power supply. Hydrogen or ammonia is used as propellant; some thrustor designs allow operation on either hydrogen or ammonia. Experimental work is also underway with mixtures of hydrogen and lithium.[2] Helium, because of its low atomic weight, its high thermal enthalpy, and the absence of molecular dissociation, would be a promising contender. However, helium has the disadvantage of low boiling point and very low heat of (CONTINUED ON PAGE 107)



This model illustrates the NASA capsule, being developed by RCA Astro-Electronics, which will carry two electric engines into a 1-hr vertical trajectory aboard the Scout vehicle in late 1962.

how difficult it was for the early engineers to design relatively complex systems without the benefit of today's powerful analytical tools. In addition, little or no analog simulation was available, and computations were limited to the slide rule or the desk calculator.

The early electronic components were large and unreliable under missile environment. Vacuum tubes were inadequate for task and magnetic-amplifier performance was poor due to the lack of satisfactory rectifiers and magnetic materials. With the available components, little could be done to reduce size and weight by changing the assembly techniques. Very little telemetry was available, making it difficult to pinpoint failures during in-flight tests.



Stable platforms are becoming much smaller, as demonstrated by the Litton P-300 which includes two-degree-of-freedom gyros, accelerometers, and four gimbals.

The development of missiles in this country after World War II was able to draw on a considerable amount of valuable experience gained during the war. Servo theory had been perfected, a very large electronics industry had been brought into existence, and analog simulation and digital computation were becoming available to the design engineer.

Miniature and subminiature vacuum tubes became available, prompting the industry to develop a line of smaller components. Better assembly techniques could now pay off, and printed circuits made their appearance. However, the real shot in the arm came with the invention and development of the transistor. With the problem caused by heat generation greatly reduced, and with newly developed miniaturized components, it was possible to greatly increase the com- (CONTINUED ON PAGE 104)

STATE OF THE ART–1961

Human Factors and Bioastronautics

BY EUGENE B. KONECCI
CHAIRMAN, ARS HUMAN FACTORS AND BIOASTRONAUTICS COMMITTEE

THE year 1961 will go down in history as immortalizing human space achievements. Men have gone into space and returned safely. The names of Yuri Gagarin, Alan Shepard, Virgil Grissom, and Gherman Titov are but the beginning of a long list of astronauts and cosmonauts. The U.S. successfully launched the first Saturn (S-I) and hopes to orbit an astronaut before year's end, or early next year, in a Mercury capsule. Additional Vostok flights are expected to follow the successful 25 hr and 18 min flight of Major Titov. Bob White of the USAF, Joe Walker of NASA, and others have taken the X-15 aircraft to record heights and speeds. The completely manned-control X-15 will continue to explore the fringes of space at altitudes above 50 mi. and speeds over 4000 mph. In addition to Gagarin's one-orbit and the Titov 17-orbit flight, the USSR also successfully recovered one dog and space zoo from Spacecraft No. 4 on March 9 and a similar payload from Spacecraft No. 5 on March 25, 1961.

STATE OF THE ART–1961

Hypersonics

BY RONALD F. PROBSTEIN
BROWN UNIVERSITY
VICE-CHAIRMAN, ARS HYPERSONICS COMMITTEE

PROGRESS in any research field is generally not measured by the number of publications, although this criterion certainly serves as an indication of the amount of effort being expended. One is therefore bound to award the hypersonics community an "A" for effort, since this writer has recorded no less than 660 new references in hypersonics during the prolific past 12 months. It is probably fair to say that this figure underestimates the actual number of publications (including reports) by at least a factor of 2. The selection of references for this review therefore necessarily represents only a limited part of the output. An attempt has been made, however, to mention representative works in addition to those papers which appear to present significant advances. But even here, we can expect only partial success, since the actual dramatic jumps in any field are often difficult to appraise at close hand.

During the past year, the main impetus for research in hypersonic, high-altitude flight with its attendant high-temperature flows has arisen from studies of lifting and nonlifting re-entry spacecraft and high-altitude boost-glide vehicles. In addition,

Astronaut Alan B. Shepard Jr. shortly before he rode MR-3 into history on May 5. Protection and monitoring of the astronaut remain problems of the first water for the human-factors field.

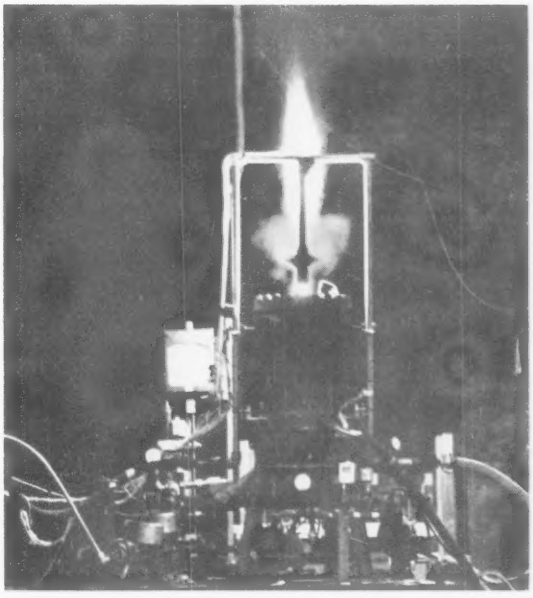
We are now on the threshold of our most fantastic bioastronautic discoveries and accomplishments. In view of the benefits that can accrue to all mankind, it is not only desirable, but mandatory, that life scientists in general, and bioastronautic specialists in particular, exchange scientific information on an international basis. Some exchange has been accomplished. For example, the Life Sciences Committee of the International Astronautical Federation, of which the American Rocket Society, Aerospace Medical Association, and American Astronautical Society are members, has as one of its prime objectives the exchange of such information. On October 1–7, the XIIth IAF Congress met in Washington, D.C., and a delegation of Soviet scientists participated in this meeting. Delegate V. J. Yazdovsky of the USSR Academy of Medical Sciences read the paper "Some Results of Physiological Reactions to Space Flight Conditions," which was co-authored by O. G. Gazenko. USSR space medicine and space biology information received in the U.S. has been relatively sparse. Yazdovsky's willingness to openly exchange information was extremely gratifying, since it will be of mutual benefit. International exchange of scientific data should be encouraged, not only by societies and committees, but by individual investigators as well. The information relative to the Soviet bioastronautic program in this article is based on a review of some of the available Soviet literature and discussions with Professor Yazdovsky.

U.S. and USSR Approaches. The American and Soviet programs for manned space flight appear to be similar. We began our rocket animal flights in the latter part of the 1940's (CONTINUED ON PAGE 117)

a great deal of work in hypersonic aerothermodynamics has been stimulated by the design of observation systems capable of yielding information on the characteristics of bodies re-entering the earth's atmosphere at hypersonic speeds from "observable" phenomena.

The hypersonic aerodynamic problems associated with atmospheric re-entry are clearly brought out by the re-entry-corridor concept first introduced by Chapman.[1] The boundaries of this corridor encompass a prescribed depth in the atmosphere within which a re-entering vehicle must return if it is not to pass out of the atmosphere again, or to encounter decelerations beyond tolerable human limits, or heating rates which would destroy the vehicle. The upper, or "overshoot," boundary of this corridor is defined as the path at which the vehicle encounters just enough atmospheric drag to slow it down so that it enters in a single pass. The lower, or "undershoot," boundary is generally determined by a deceleration limit which is usually taken to be 10 g's for manned re-entry. Both of these boundaries may also be heating-limited.

The work of Chapman has shown that the depth of the corridor is a function of the lift-drag (L/D) ratio of the vehicle and of the vehicle entrance speed into the atmosphere. The (CONTINUED ON PAGE 121)



The study of turbulent ablation in air-arc simulation facilities such as this one, described by W. R. Warren and N. S. Diaconis of GE's Missile and Space Vehicle Dept. in a paper given at the ARS International Hypersonics Conference, plays an important role in advancing hypersonic aerodynamics.

STATE OF THE ART–1961

Liquid Rockets

BY MARTIN GOLDSMITH
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AND ROLF H. SABERSKY
CALIFORNIA INSTITUTE OF TECHNOLOGY
MEMBER, ARS LIQUID ROCKETS COMMITTEE

WITHOUT doubt, the subject of most interest in the area of astronautics today is manned exploration of the moon. Because of the time schedule that has been proposed for accomplishing this task, it will be necessary to depend largely on the state of the art for at least the first voyages. Let us attempt to assess then the capability of the liquid-propellant rocket engine applied to this mission.

The manned lunar mission imposes three general requirements. The first concerns performing course corrections and maneuvering for landing on the moon's surface. In this task, controllability is of special importance, while neither very large thrust nor high performance are necessary. The second concerns imparting large velocity gains. This task is performed by the upper stages of the propulsion vehicle; high performance is of great importance here. The third requirement concerns boosting the space vehicle through the atmosphere. Very high thrust and a large total impulse are required in this portion of the flight; high specific impulse and efficient structure are of lesser consequence.

In terms set forth here last year,[1] it would appear that the liquid rocket has the capability to satisfy all of these requirements. Throttling and restart have been demonstrated, most notably in the X-15 engine, where these operations are performed under the pilot's control. The upper-stage requirement for high performance is being met by the hydrogen-oxygen engines under development for NASA; and a $1^1/_2$-million-lb-thrust lox-kerosene

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Magnetohydrodynamics

BY MILTON M. SLAWSKY
AF OFFICE OF SCIENTIFIC RESEARCH
CHAIRMAN, ARS MAGNETOHYDRODYNAMICS COMMITTEE

DURING this year, magnetohydrodynamics, or magnetofluiddynamics, received special attention from the scientific and engineering community on three different occasions. The AIEE, IAS, and IRE jointly sponsored the Symposium on Engineering Aspects of Magnetohydrodynamics on March 9–10 at the Univ. of Pennsylvania; the ARS Biennial Gas Dynamics Symposium was held at Northwestern Univ. on August 23–25; and the International Atomic Energy Agency conducted the Conference on Plasma Physics and Controlled Nuclear Fusion Research in Salzburg, Austria, during September 4–9. There were about 250 papers submitted to this latter conference. Of these, 110 papers were accepted for oral presentation. These will be published in the IAEA journal *Nuclear Fusion* together with the abstracts of the other 140 papers. It might be interesting to note that of the 250 papers, the Americans contributed 75 and the Russians 60.

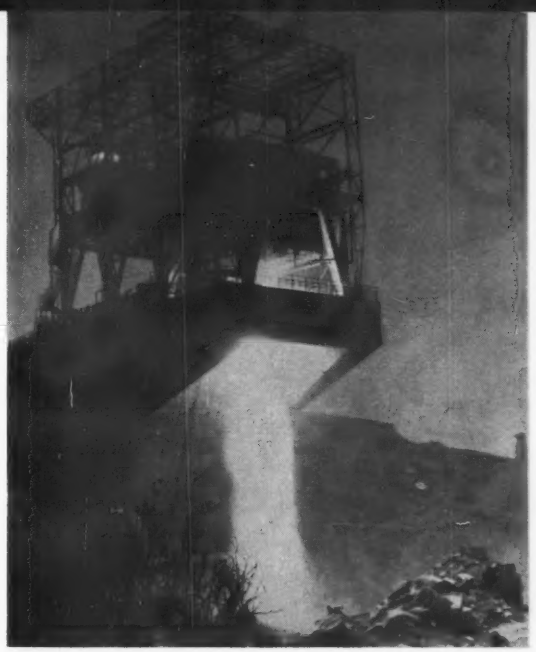
MHD continues to be a fertile hunting ground for physicists and engineers. It is a science which combines physical and engineering disciplines. In fact, the depth of understanding and the sophisti-

engine, which could form an element of various large boosters, is already under test. Thus one might be very confident that the propulsion problems of lunar exploration are within our capability.

Liquids Show Reliability

However, due in part to its actual failings, and due perhaps to an even higher degree to exaggerated publicity, the liquid-rocket engine is often considered an expensive and unreliable propulsion device. This image has been rather firmly rooted in the minds of many people. Actually, however, a dispassionate calculation of propulsion-system reliability will reveal that the liquid rocket, while not perfect, has even in its present state of development established a very satisfactory record of dependability. For example, a flight-stage reliability (of the liquid-rocket propulsion system, including tanks, etc.) of about 90% has been achieved in the U.S. space program to date.[2,3]

Nevertheless, delays, (CONTINUED ON PAGE 113)



A single-chamber F-1 engine booms out over 1-million-lb thrust in a static test. The big engine, under development for NASA by Rocketdyne, employs conventional liquid propellants (LOX-RP) and marks an attempt to combine great power with reliability and ease of performance. These factors, the authors conclude, will pace the development of future large liquid rockets.

cated thinking required for effective work with plasmas has had a very considerable effect on engineering education. It has accelerated the conversion of engineering from an art to a science. The change is most noticeable in aeronautical engineering. The advent of hypersonic flight took the aerodynamist from an atmosphere of ideal gases to that of real gases. Then space flight took him, not into vacuum, but into an atmosphere of charged particles and electromagnetic fields. Fortunately, the foundation for stepping into this area had been laid. Neither plasma nor electromagnetic theory was really new. It was the combination that presented a host of new phenomena. The aerodynamist saw these as the dynamics of a conducting fluid, subjected to electromagnetic forces defined by the Maxwell equations. The physicist, on the other hand, saw these phenomena as an extension of electrodynamics of a single charged particle, that is, from mechanics to statistical mechanics of charged particles.

This year the interest in MHD had its major stimulus from two technological areas: (1) The controlled-nuclear-fusion program and (2) the electromagnetic-propulsion and the electric-power-generation programs. Additional incentives were provided by problems in hypersonic-flight simulation and by astrophysical phenomena.

The two biggest technological problems of MHD related to controlled nuclear fusion are (1) to make hot (10^4 ev or 10^8 K), dense (10^{20} ions/m^3) plasma and (2) to contain this plasma for a reasonable time (1 sec). The accepted condition for fusion is that the density multiplied by the containment time must be of the order of 10^{20} in the above units. Neither problem is likely to be solved by brute-force methods or recourse to existing knowledge. Neither the heating nor the heat loss are simply related to similar phenomena in gases at more moderate temperatures. Similarly, containment of hot plasma cannot be accomplished by direct contact with material walls. The difficulty is not with excessive heating of the walls but with excessive cooling of the plasma. The containment must be done with magnetic fields.

Serious Attack Begins

After the first flurry of optimism born of naivete and subsequent sobering failures, the really serious scientific attack on the (CONTINUED ON PAGE 115)

STATE OF THE ART–1961

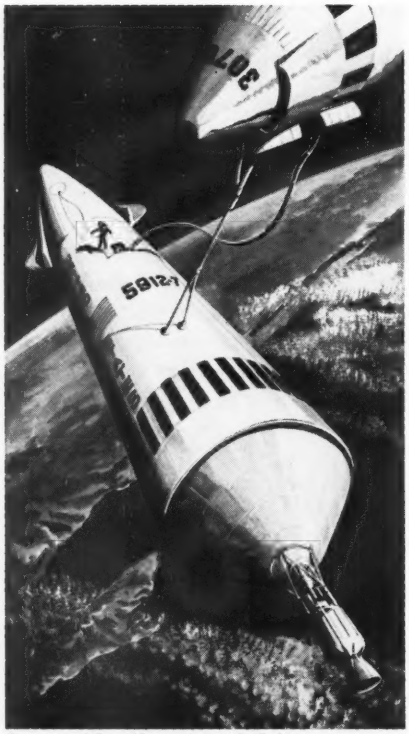
Missiles and Space Vehicles

BY WILLIAM M. DUKE
SPACE TECHNOLOGY LABORATORIES
CHAIRMAN, ARS MISSILES AND SPACE VEHICLES COMMITTEE

THE most dramatic accomplishments, in the popular sense, during the past year were the two manned suborbital flights of the Mercury capsule. Who knows how many lives might be saved in the future because of the loss of the second Mercury capsule? Other events during this period, although not making the same kind of splash before the eyes of millions of TV viewers as the recovery at sea of the astronauts and the Freedom 7 capsule, might in the long run prove more important.

Missile development shared the headlines with Project Mercury during this period, as milestones whizzed by. Three and one-half years after go-ahead, the Minuteman missile scored a success on its first test flight, thus adding a stiffening agent to our military posture– and, incidentally, giving much comfort to the proponents of solid-propellant vehicles. An Atlas-E model set a distance record of 9000 mi. from the Atlantic Missile Range. Titan I was launched successfully from in-silo as well as from a silo-lift installation. The noncryogenic Titan II progressed steadily; its new inertial guidance system was flight tested in Titan I. The most powerful solid-propellant rocket known was fired– a 100-in.-diam Aerojet-General segmented rocket producing a thrust of more than 500,000 lb. Several operational Polaris submarines were commissioned.

There were new spacecraft placed in orbit: Samos II, Midas III, and Ranger I. Additional members of well-known (CONTINUED ON PAGE 78)



Courtesy of Los Alamos Scientific Laboratory

STATE OF THE ART–1961

Nuclear Propulsion

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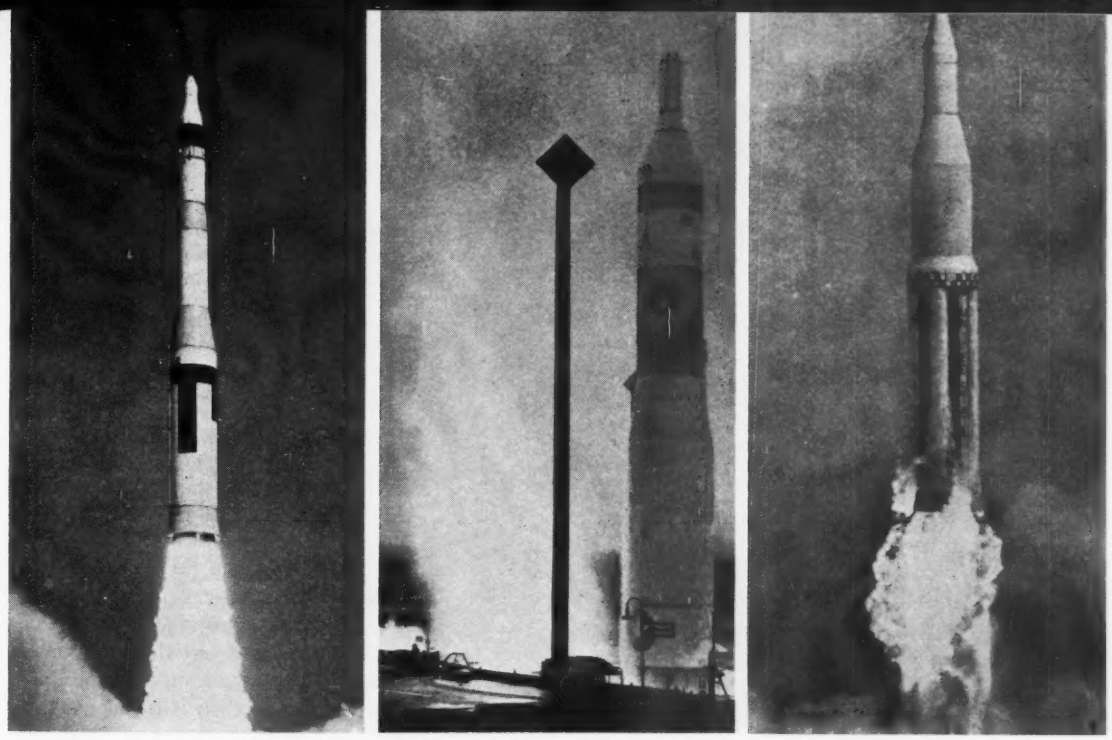
UC LAWRENCE RADIATION LABORATORY
MEMBERS, ARS NUCLEAR PROPULSION COMMITTEE

Artists' conception of a Nerva-engined space vehicle being refueled in orbit about the earth.



Up! Up! Up! From left, Minuteman takes off in its first flight test February 1, a resounding success, which encouraged solid-rocket advocates in plans for large solid space boosters; a modified Titan I rises from the bottom of a 146-ft-deep silo on May 3, its successful performance advancing development of silo launching with liquid-propellant ICBMs; and Saturn S-1 puts the U.S. on a new level of rocket operations as it takes off October 27.

PROGRESS in nuclear propulsion continued at a rapid pace throughout the year in both the ramjet- and rocket-propulsion fields.

In the rocket (Rover) program, perhaps the most significant development has been the large expansion of work into the missile and nuclear industry, at last beginning to tap the national manpower and technology resources which must eventually carry the burden of a full-fledged and vigorous nuclear-rocket program aimed toward practical manned space flight. This was possible because of the experience gained from the Kiwi-A series of reactor tests, just completed by the time of last year's report.

Nerva Contract a Big Step

The single most important step forward was taken with the letting of the first-phase contract for work on the Nerva engine program, with Aerojet-General selected as prime contractor for the over-all engine development and Westinghouse Electric as associate contractor for nuclear-reactor aspects of the complete engine.

The drawing on page 44 is an artist's conception of an early application of this nuclear rocket engine. Other industry-based work included continued development of nozzles and turbopumps for nuclear-rocket applications by Rocketdyne; study of the requirements of a National Nuclear Rocket Development Center by the Ralph M. Parsons Co.; further Rift (Reactor In-Flight Test) studies by Douglas Aircraft, Lockheed Aircraft, GD/Astronautics, and the Martin Co.; and continued work in direct support of the Los Alamos program by the Bendix Corp. on reactor-control development; by ACF Industries on structural design, fabrication of components, and development and fabrication of equipment for use in reactor testing in Nevada; by Brush Beryllium for fabrication of reactor parts; by Edgerton, Germeshausen, and Grier in the development, construction, and installation of Nevada Test Site (NTS) instrumentation; and by Aetron, Vitro Engineering, Air Products and Chemicals, Holmes and Narver, and a variety of construction contractors in the expansion of NTS facilities for future reactor testing.

In short, nuclear-rocket development has begun to become "big business" in the American missile-industrial world. To administer this expanding interdisciplinary effort, the (CONTINUED ON PAGE 127)

STATE OF THE ART–1961

Physics of the Atmosphere and Space

BY HERBERT FRIEDMAN
U.S. NAVAL RESEARCH LABORATORY
CHAIRMAN, ARS PHYSICS OF THE ATMOSPHERE AND SPACE COMMITTEE

SPACE physics was characterized during the past year by the broad range of problems from aeronomy to astrophysics which came under investigation. The items mentioned below are a sampling of some of the more important accomplishments.

Aeronomy. The first COSPAR International Reference Atmosphere was published following the 1961 meeting in Florence. Although the new tabulations will be extremely useful, equally important was the recognition by H. Kallmann-Bijl and her collaborators in this project that there remain vast areas of ignorance in the subject of "aeronomy."

A major correction to previous models originated with M. Nicolet, who pointed out the importance of helium in the exosphere and succeeded in explaining, thereby, the apparently anomalous high drag shown by the Echo I satellite near 1500 km. Nicolet demonstrated that the Echo I drag data of Zadunaisky, Shapiro, and Jones and of Romer could not be explained by a purely (CONTINUED ON PAGE 92)

STATE OF THE ART–1961

Power Systems

BY JOHN H. HUTH
RAND CORPORATION
CHAIRMAN, ARS POWER SYSTEMS COMMITTEE

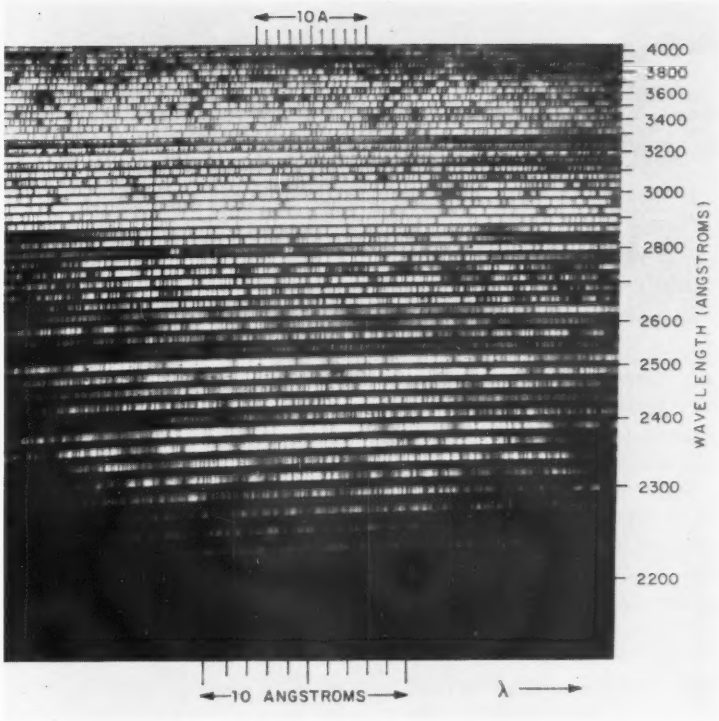
DURING 1961, a number of interesting and fundamental developments have occurred in energy conversion which portend considerably improved power systems.

Thermocouples. The efficiency of a thermocouple may be expressed in terms of the dimensionless parameter, ZT, where T is a temperature and Z the so-called "figure-of-merit." The Z itself can be expressed by $Z = \alpha^2\sigma/k$ where α is the Seebeck coefficient (can be shown to be the average entropy transported by a charge carrier, per unit charge), σ the electrical conductivity, and k represents thermal conductivity. Specifically, over-all efficiency (heat to electricity) may be expressed as follows:

$$N = N_c \left[\frac{\sqrt{1+ZT}-1}{\sqrt{1+ZT}+\frac{T_c}{T_n}} \right]$$

In this expression, N_c represents the efficiency of a Carnot engine operating between a hot junction temperature, T_n, and a cold junction temperature, T_c. Here T represents the average of T_n and T_c.

The band theory of metals has provided some guidelines for the selection of materials of maximum Z; namely, that the number of free electrons/cc



The first high-resolution solar spectrum in the rocket ultraviolet enlarged from an original 1-in. square, obtained by NRL's D. G. Garrett, J. D. Purcell, and R. Tousey from an Aerobee-Hi sounding rocket launched August 29. By means of an echelle design, this very long spectrum was folded and compressed to fit into the small space available in the rocket. The many thousands of Fraunhofer absorption lines are produced by the different elements in the sun's atmosphere. Because the lines are well separated by the extremely high dispersion of the echelle instrument, the presence of elements not yet detected in the sun is likely to be established and their chemical abundance determined.

should be 10^{19}. The optimization goes as follows: Electrical conductivity increases linearity with carrier concentration. At the same time the electronic contribution to head conductivity will also increase linearly, while the lattice contribution will remain essentially constant. The Seebeck coefficient decreases with increasing carrier concentration. The net result of these effects is an optimum carrier concentration around 10^{19}/cc.

However, during the past year some high-temperature materials which have turned out to be promising exhibit properties which do not fit well into any present theory. I refer here to the rare-earth sulfides, in which carrier concentrations may run as high as $10^{22}/cm^3$, depending on the stoichiometry. Values of $ZT \cong 0.3$ have been obtained in the 1000-C temperature range with these materials, and it seems quite likely that values of ZT somewhat greater than unity are in the offing.

However, this would still imply single-element efficiencies only about one-third those of Carnot. Of course, such high-temperature elements can be cascaded with low-temperature units. Another reason for continued interest in thermocouples is their use as a substitute for solar cells. Reportedly, thermocouple sandwiches can be made at one-fifth the weight and one-tenth the cost of present solar-cell configurations for comparable output.[1] Also, the thermocouples are presumably more radiation-resistant. However, the efficiency of such sandwiches in space would only be about one-third that of present solar cells.

New Thermocouple Applications

A further application may be to cooling of electronic elements. Here, as in other applications, a number of elements must be connected in series and packed in a small space. One tries, of course, to take advantage of the fact that, aside from contact resistance, the performance of a couple will be unaffected if its length and cross-sectional area are cut in the same ratio.

In the lower temperature range (300–900 K) a widely used thermoelectric material is doped PbTe with a figure of merit (Z) of about 1.5×10^{-3} reciprocal degrees Kelvin. (In lead telluride, the carrier concentration is near the "band-theory" optimum.) The best actual (CONTINUED ON PAGE 96)

STATE OF THE ART–1961

Propellants and Combustion

BY PETER L. NICHOLS, JR.
AEROJET-GENERAL CORPORATION
CHAIRMAN, ARS PROPELLANTS AND COMBUSTION COMMITTEE

ACTIVITY in the propellant field has been increasing rapidly to keep pace with the expanding scale of space experiments. Also, this activity is heightened by the development of a multitude of military rockets reflecting the increasing tension in world affairs. Advanced planning on rockets of sizes required for manned space vehicles is taking into consideration the possibilities of both solid and liquid propellants. In fact, there has been active consideration and work on practically every conceivable type of chemical propulsion system. Hybrid rockets have been a popular topic of conversation, but there have been no significant developments reported in this area beyond studies of the combustion problem in hybrid systems. It is interesting to note that for many years the hybrid concept was not very popular and engineers often claimed that hybrid systems combined the worst features of both solids and liquids. For specific applications, their relatively high specific impulse and the possibility of producing a throttleable engine have brought them some consideration.

The competition between the advocates of solid and liquid propellants remains strong. There have

STATE OF THE ART–1961

Ramjets

BY WILLIAM H. AVERY
APPLIED PHYSICS LABORATORY, JOHNS HOPKINS UNIVERSITY
CHAIRMAN, ARS RAMJETS COMMITTEE

THE year 1961 was notable for bringing public recognition to two important military applications of ramjet engines and for major progress toward demonstration of the outstanding potentialities of hypersonic air-breathing systems for terrestrial and satellite-booster missions.

In the military application of ramjet engines, both the Air Force and Navy successfully demonstrated the superior performance of

The 35th Bomarc-B missile launches into a successful flight September 7 and brings to a close the Model B experimental flight-test program. One Bomarc-B winged 446 mi. to intercept a target at 100,000-ft altitude.

Looking through the perforation of one solid-propellant segment of the $8^1/_3$-ft-diam, 500,000-lb-thrust motor built and static-fired by Aerojet-General for the Air Force. The physical properties of such large solid rockets have become a very important area of work.

been interesting developments during the past year as to application of both systems to large boosters. In the NASA space program, as presently planned, large vehicles such as Centaur, Saturn, and Nova will use oxygen and RP fuels in the first stage. During the past year, the concept of the segmented solid rocket has advanced considerably, in view of the success of firing large motors with several segments and the attainment of a successful rocket test firing of one-half-million pounds of thrust. The photo at the top of this page brings to focus the enormous size of the segments used in these large solid engines. The ease of achieving high-thrust levels combined with the potential of high reliability in solid engines have warranted their consideration for large-booster applications.

The use of propellants in space has brought about a number of new considerations which are important in the selection of propellant systems. The whole problem of determining what is storable in space has been given quite a bit of attention during the past year. The question of the storability of hydrogen has been particularly important, and several articles have ap- (CONTINUED ON PAGE 100)

these powerplants for long-range anti-aircraft missiles.

On September 7 Boeing announced the successful completion of the Bomarc-B experimental flight-test program with the successful firing of the 35th Model-B missile, shown on the opposite page.

A highlight of the test program was a "maximum range" demonstration, in which one of the missiles performed an intercept 400 mi. from the launch site at an altitude well above 60,000 ft. Equally important minimum-range and minimum-altitude tests also were performed satisfactorily. Targets included unmanned F-80 jet fighters, B-47 jet bombers, and the 1000-mph Regulus II missile.

Early in 1961, Bomarc-B entered Step 2 of flight testing. Tactical versions of the missile are being fired from Eglin AFB as a part of AF's crew-training and missile-service test program. On March 3, an IM-99B made its first full-range flight, winging out over the Gulf a distance of 446 mi. to intercept its target at an altitude of 100,000 ft.

Very similar in outward appearance to the present Model A, the Bomarc-B incorporates improved ramjet engines, a solid-propellant rocket booster for acceleration to flight speed, and an advanced target-seeker which can search a corridor from sea level to an undisclosed maximum altitude. The Marquardt Corp., which manufactures the Model-B ramjets, has reported testing these engines on a flight vehicle at Mach 4 speeds and at 100,000-ft altitude. The new ramjets burn JP-4 jet fuel, readily available at AF bases. The solid booster for the Model-B is produced by Thiokol Chemical. Both models of the IM-99 Bomarc are manufactured by Boeing at its Missile Production Center in Seattle. An interesting summary of the history and status of this program was given by the Hon. M. Blaine Peterson of Utah to the House of Representatives on Aug. 29, 1961.[1]

Typhon Spearheads Development

On October 13, the Navy announced award of a contract to the Bendix Corp. for development of a long-range missile called Typhon LR, which is designed to provide greatly increased protection to the fleet. The weapon will be able to attack both aircraft and missiles. Typhon LR will be propelled by a ramjet engine that marks a major step forward in the application of air-breathing propulsion. Details of the engine (CONTINUED ON PAGE 102)

STATE OF THE ART–1961

Solid Propellant Rockets

BY G. DANIEL BREWER
LOCKHEED PROPULSION COMPANY
CHAIRMAN, ARS SOLID PROPELLANT ROCKETS COMMITTEE

SOLID-propellant rocketry is finally emerging from the shell of conservative thinking which has to date relegated it to a position of secondary importance in the missile propulsion industry. The magnificent success of Minuteman on its first flight February 1 proved beyond doubt that solid-propellant rocket engines are capable of performing a major role in the big-missile propulsion field.

As though heartened by the Minuteman success, in April and May of 1961 representatives of the solid-rocket industry went before the House of Representatives Science and Astronautics Committee, chaired by the late Overton Brooks, to present their case for building very large solid rockets for boosting the Saturn- and Nova-class space vehicles planned by NASA for development and use in the next decade. Their testimony fell on sympathetic ears and the Committee recommended that $50 million be provided immediately for development of big solid booster engines. In his fiscal budget for 1962, President Kennedy asked Congress to provide $62 million to develop big solid boosters, so that both big solid and liquid engines could be developed until it was certain which was superior. The money was allocated. (CONTINUED ON PAGE 125)

STATE OF THE ART–1961

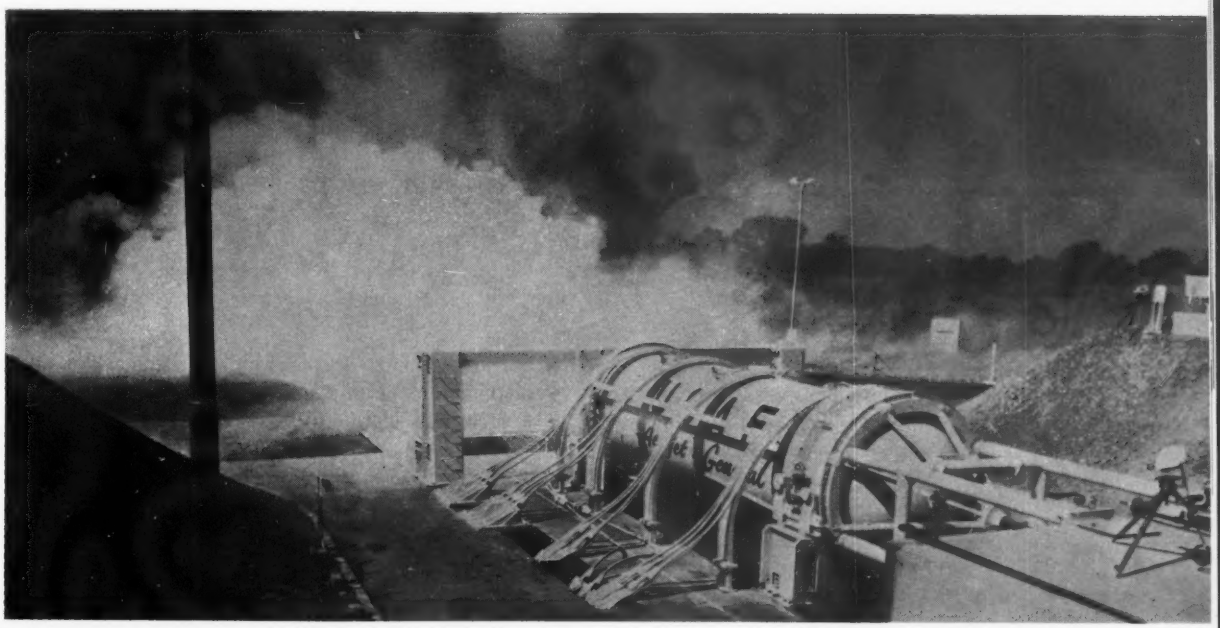
Space Law and Sociology

BY ANDREW G. HALEY
HALEY, WOLLENBERG AND BADER
CHAIRMAN, ARS SPACE LAW AND SOCIOLOGY COMMITTEE

FIVE years of intensive writing on space law culminated in 1961 in the production of an almost unassimilable mass of books, speeches, papers, articles, and other possibly valuable data—little of which follows a logical pattern. Indeed, one might state without fear of challenge that 90% of the discussions of so-called space law are wholly undisciplined and actually most are purely political polemics.

The adduction of baseline data by the sociologists has yielded a greater challenge of informed conclusions, but even the sociologists have not withstood the temptation to talk solely in the terms of politics and to speculate upon the problems of the future without considering the data concerning man on earth which may be posited as useful guides to help determine the status of man in space.

Only a small group of lawyers had actually considered the implications of and problems created by existing *law*. To effect desirable, and indeed



Four-segment solid rocket developing 500,000-lb thrust thunders through static firing at Aerojet-General's Sacramento facilities on August 26.

necessary changes in the laws of nations and in terrestrial international law, a great many changes must be made to legitimatize many essential prospects of space law. The Constitution of the U.S. and of scores of other nations may have to be revised. Certainly thousands of changes must be made in national municipal law and in even the broad field of international treaties. The mechanics of adjusting existing law to the requirements of space law have scarcely been thought of by the legal commentators.

Formal Legal Work Needed

Even the source material—the "tools" of the legal technician—has been neglected. There are, however, a few bright spots. For example, in 1956 this writer asked Senator Warren G. Magnuson to suggest that the Library of Congress compile and translate the air laws and treaties of the world to assist the researcher in space law. This task was undertaken by the Library of Congress and one most highly beneficial product has been the publication of "Air Laws and Treaties of the World," published on May 11, 1961, under the direction of William S. Strauss. Charles F. Ducander, executive director and chief counsel of the Committee on Science and Astronautics of the U.S. House of Representatives, advised Chairman Brooks as follows:

> This report will fill a great and immediate need in the field of aviation law. Furthermore, there is a close technical, and hence legal, relationship between navigation in the air space and that in outer space. Indeed, air space and outer space are inseparable. The Congress recognizes this relationship in the National Aeronautics and Space Act of 1958, which authorized the National Aeronautics and Space Administration to deal with problems "involved in the utilization of aeronautical and space activities." In the "Survey of Space Law" (H. Doc, No. 89, 86th Congress), issued by the Committee on Science and Astronautics, the following questions were raised as to common legal problems in air and space activities:
>
> 1. What is the legal boundary between air space and outer space?
> 2. Do present international conventions for the regulation of civil aviation apply to space flight?
> 3. What is the relation to space flight of national aviation laws?
> 4. How can international agreement be reached on space jurisdiction and other basic matters of definition and classification?
> 5. What legal liabilities arise from injury or damage caused by space vehicles?
> 6. What provisions should be made for the ownership and commercial use of space re- (CONTINUED ON PAGE 90)

STATE OF THE ART–1961

Structures and Materials

BY NORRIS DOW
GE SPACE SCIENCES LABORATORY
MEMBER, ARS STRUCTURES AND MATERIALS COMMITTEE

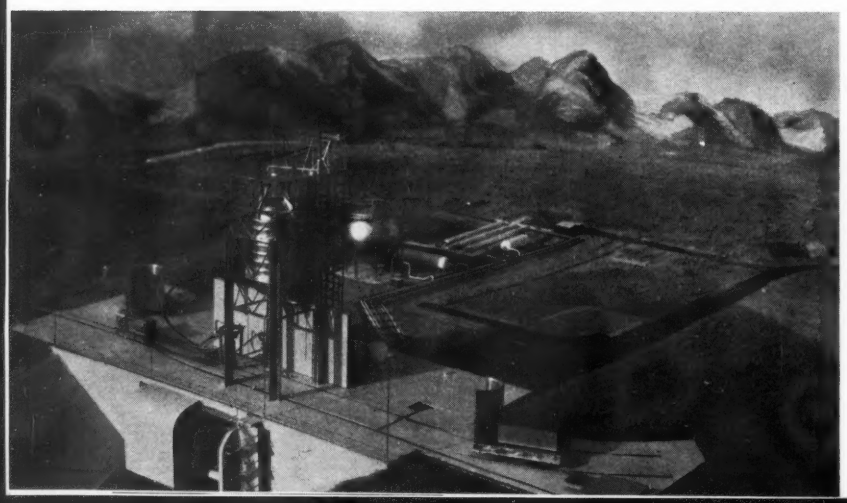
IN the field of structures and materials, the year 1961 has been characterized by a variety of technical refinements and by developments which give promise of possible major advances, but not by any actual breakthroughs. The success of this year's ARS Structures and Materials Specialists Conference at Palm Springs, continuing that of the Santa Barbara Conference last year, has firmly established the American Rocket Society as a recognized leader in the structures and materials field. The integration of structures and materials, the theme of these conferences, has continued to receive increasing endorsement and, as the following summarizations demonstrate, an implementation which is beginning to yield significant results.

Composite Materials. The first actual utilization of the high strength of fine filamentary single crystals, or whiskers, to reinforce metal was reported by G. W. Sutton at Palm Springs. This is a material development deriving in part from previous structural studies and analyses. While still a long way from an available structural material, the test sample did show that potentially the "super-strengths" of whiskers are accessible for actual application.

STATE OF THE ART–1961

Test, Operations and Support

BY BERNHARDT L. DORMAN
AEROJET-GENERAL CORPORATION
CHAIRMAN, ARS TEST, OPERATIONS AND SUPPORT COMMITTEE



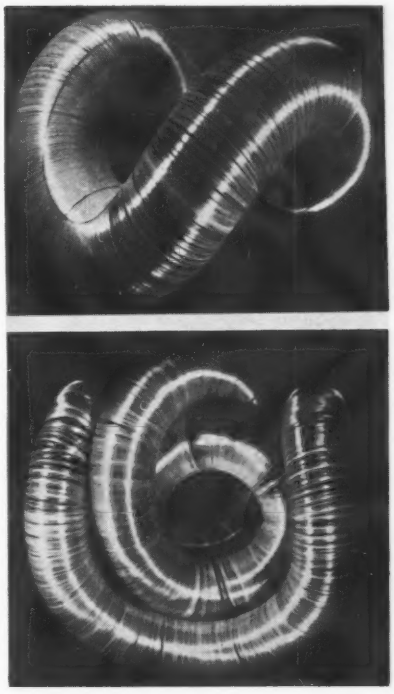
Model of first "down-firing" test stand for nuclear rocket engines under construction at the AEC's Nevada Test Site.

In a not unrelated development, Scruggs reported at the same meeting the development of what might be described as a "ceramic alloy" of chromium having attractive properties in the 3000-F temperature range. The same technique of reinforcing with ceramic particles, found applicable to chromium, should be capable of extension to other metals.

The more conventional use of filaments for reinforcement was extended during the year by Gruntfest to the use of other shapes than solid rounds. In particular, the use of hollow filaments yielded one of the first improvements in strength-to-weight ratios by decreasing density.

Thermal Protection. A major proportion of the effort on thermal-protection systems this year has gone into the study of the application of cooling systems involving vaporization or other mechanisms of mass removal to the long thermal exposures of gradual re-entry. Thorough investigations of the penetration of heat into combination systems employing ablation, insulation, and heat-sink characteristics have been carried out by Collins, Hurwicz, et al. Specific studies of the utilization of the unusual thermal anisotropy of pyrolytic graphite for the same type of application were conducted by Nolan and Scala, and the use of internal, wick-like structural coolants was evaluated by Alvis and Whisenhunt, and by Pride (among others). Thus the capabilities of these essentially "active" systems have now been fairly thoroughly delineated, and the (CONTINUED ON PAGE 62)

Instability of Isotensoid Torus



TEST, operations, and support of today's military and space vehicles involve an estimated 60 to 70% of the total effort associated with vehicle development and ultimate deployment. A state-of-the-art report covering the broad range of technologies involved in an activity of this magnitude can only touch on the highlights of 1961 accomplishments. A partial list would include the following:

- Static testing of $1^1/_2$-million-lb-thrust rocket-propulsion systems at regular and increasing frequencies.
- Preparing to launch vehicles weighing more than 1-million lb.
- Successfully launching full-scale liquid-propellant missiles directly from silos fully simulating tactical deployment.
- Installing new tracking and radar systems to provide more than 100% improvement in skin-track capability and range and angular accuracy.
- Outfitting surface ships as mobile tracking stations in preparation for obtaining trajectory data when space vehicles transfer from parking orbits to new orbits.
- Adopting automatic and digital checkout systems to reduce checkout time and improve reliability of our increasingly complex space vehicles.
- Operating or constructing altitude chambers with maximum dimensions to 80 ft that provide steady-state vacuum pressures of 0.03 psi and space chambers that attempt to simulate known environments of solar and other radiations, temperature variations, and micrometeoroid bombardment. (CONTINUED ON PAGE 69)

Complete F-1 engine fires on nation's largest engine test stand at NASA High Thrust Test Area, Edwards, Calif.

STATE OF THE ART–1961

Underwater Propulsion

BY HERMAN E. SHEETS
GD/ELECTRIC BOAT DIV.
CHAIRMAN, ARS UNDERWATER PROPULSION COMMITTEE

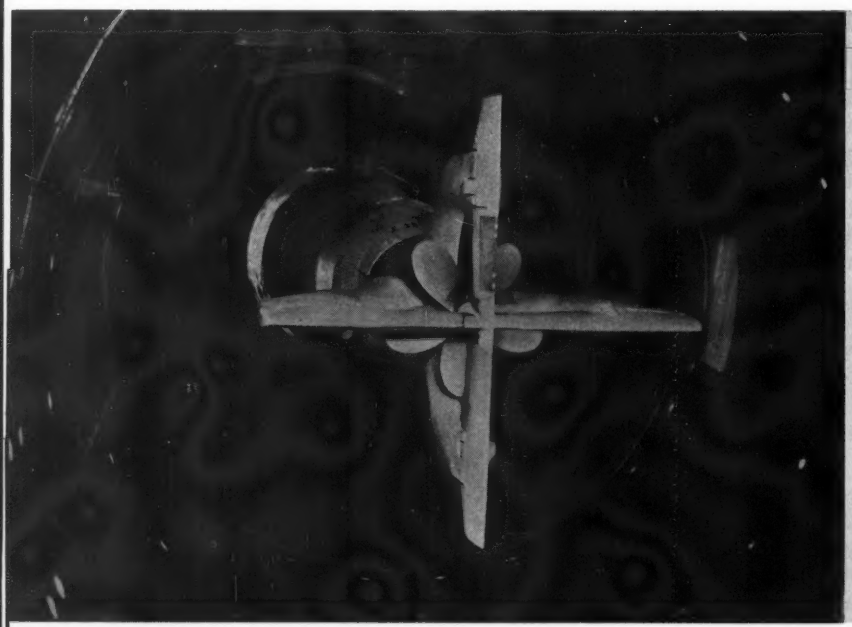
THE field of underwater propulsion covers a wide range of applications–from very small craft operating for a short time to very large submarines operating at high speed for a long time. The total horsepower-hours for which a powerplant and fuel must be provided is a significant factor in determining the optimum underwater propulsion system. At one end of the propulsion spectrum, nuclear systems of proven reliability have revolutionized the field, not only permitting long, sustained underwater travel but also increasing the entire performance of underwater vehicles with regard to speed, maneuverability, depth, and reliability.

During the past year, the ARS Committee on Underwater Propulsion held two meetings sponsoring papers relating to the other end of the propulsion spectrum–propulsion systems operating for relatively short durations in fairly small craft (low hp-hr). Such propulsion systems have uses for torpedoes and related special applications. The energy sources available for low hp-hr systems are presently non-nuclear and, since they cannot use atmospheric air, require the transport of oxidizers to sustain combustion. These systems are in many ways like those for space propulsion and entail similar problems of technical development.

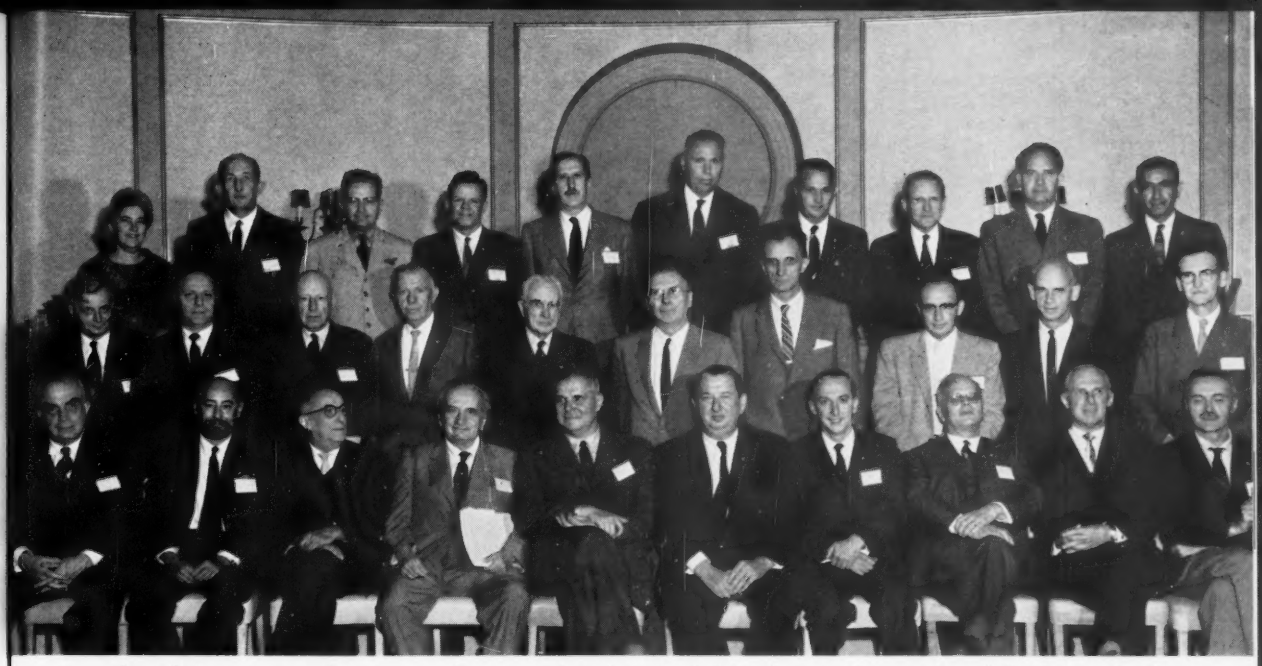
Using the Medium

There are significant differences, however, particularly the effects of variable back pressure caused by the requirement to operate over a range of depth. In addition, both water and pressure, which increases with the distance from the interface, may participate in the propulsion process. For instance, in chemical processes the water may be used both as an oxidizer and a diluent.

The problems of underwater propulsion are similar to those of rocket propulsion in that during the last few years an effort has been made to increase performance in terms of speed and range, all hopefully to be accomplished within the same space and weight, resulting in a (CONTINUED ON PAGE 72)



The prospect of extensive explorations of "inner space" provides one spur to the study of advanced underwater vehicles, as represented, for instance, by this model of the experimental submarine Albacore, shown in the large water tunnel of Pennsylvania State Univ.



A number of the representatives from various countries who attended the first regular meeting of the International Academy of Astronautics in Washington, D.C., last October 3, pose for the photographer. In the front row, left to right, are N. Boneff (Bulgaria), F. J. Malina (USA), J. Peres (France), Theodore von Karman (USA), R. Pesek (Czechoslavakia), A. G. Haley (USA), L. R. Shepherd (UK), E. A. Brun (France), R. Grandpierre (France), and R. Margaria (Italy). In the middle row, left to right, are J. M. J. Kooy (Netherlands), E. Carafoli (Rumania), A. Meyer (German Federal Republic), H. Strughold, J. C. Cooper, H. L. Dryden, A. Busemann, M. Summerfield, and E. Stuhlinger (all from the USA), and U. S. von Euler (Sweden). In the top row, left to right, are H. van Gelder (USA), J. Vannucci (Italy), J. P. Stapp and H. S. Seifert (USA), T. M. Tabanera (Argentina), L. Broglio (Italy), A. Ferri (USA), A. Eula (Italy), V. Guth (Czechoslavakia), and H. Friedman (USA).

Report on the International Academy of Astronautics

Theodore von Karman elected director . . . New committees established on relativity theory and astronautical history . . . Sir Bernard Lovell receives first Guggenheim International Astronautics Award of $1000

By Andrew G. Haley

HALEY, WOLLENBERG & BADER, WASHINGTON, D.C.

THE first regular meeting of the International Academy of Astronautics was held on October 3, 1961, at Washington, D.C., under the chairmanship of Theodore von Karman, its director. Establishment of the Academy with headquarters near Paris, France, had been approved by the International Astronautical Federation (IAF) on Aug. 15, 1960.

The original membership of 45 has since grown to 76 members from 18 countries, including one Honorary Member, Niels Bohr of Denmark, with additional members to be elected before the end of 1961. The Academy comprises three sections: Basic Sciences, Engineering Sciences, and Life Sciences.

In his report on the activities of the past year, Dr. von Karman gave an account of the Academy's first symposium held June 19-21 near Paris, France. He related that 16 papers by scientists from nine countries were presented at the symposium, which was divided into four sections: Trajectories for lunar and interplanetary missions, orbital transfer and rendezvous, near-earth (CONTINUED ON PAGE 74)

The first plenary session of the XIIth International Astronautical Congress begins Monday morning, October 2nd, at the Georgetown Univ. Institute of Languages and Linguistics. Congress Chairman Samuel Herrick, at the head of the table, with microphone, welcomes delegates. IAF President Leonid Sedov of the USSR, seated just to Dr. Herrick's right, later rose to open the proceedings formally.

France's Peres heads IAF

1000 attend first Congress held in U.S. . . . Pickering among newly elected vice-presidents . . . '62 Congress to be held in Bulgaria . . . New Constitution adopted . . . International Program Committee formed

By Irwin Hersey and John Newbauer

THE XIIth International Astronautical Congress, held at the Marriott Twin Bridges Motor Hotel in Washington, D.C., October 2–7, drew the largest attendance in the 12-year history of the International Astronautical Federation, attracting 1000 scientists, engineers, and guests, including some 300 foreign visitors from more than 30 different countries.

ARS acted as host society for the meeting—the first to be held in the U.S.—in cooperation with the two other American IAF members, the American Astronautical Society and the Aero-Space Medical

Hugh Dryden, NASA Deputy Administrator, cites the need of wide public support and international cooperation in space exploration in his address to the Congress during opening ceremonies at the Smithsonian Institution. Visible on the platform, from left, T. von Karman, N. Khabarin (interpreter), L. Sedov, L. R. Shepherd, and H. Seifert.

Assn. Samuel Herrick, Hunsaker Professor of Aeronautical Engineering at MIT, was general chairman of the Congress.

J. C. Peres of France, member of the French Academy of Science, former dean of the faculty of science of the Univ. of Paris, and professor of applied mathematics and fluid mechanics at the Sorbonne, was unanimously elected president of the IAF for the coming year, succeeding Leonid I. Sedov of the Soviet Academy of Sciences.

The newly elected IAF vice-presidents are Leslie R. Shepherd of England, William H. Pickering of the U.S., Nicolas Boneff of Bulgaria, and Teofilo M. Tabanera of Argentina. Andrew G. Haley of the U.S. was re-elected IAF general counsel and Josef Stemmer of Switzerland was re-elected honorary secretary.

The USSR relinquished its claim to one of the vice-presidencies since Professor Sedov will have a vote on the IAF Bureau as immediate past president.

The 1962 Congress will be held in Sofia, Bulgaria, in mid-October, while Buenos Aires, Argentina, has been selected as the site of the 1963 meeting.

Two major steps aimed at strengthening the IAF were taken at the plenary sessions at the Congress. The first was the unanimous adoption of the revised draft of a new IAF constitution, and the second was the formation of an International Program Committee to aid in organizing the technical programs of future Congresses.

The new constitution, sent back to Committee after long discussion at the Stockholm Congress last year, was adopted, in the words of Professor Sedov, "as a working document subject to change in the light of experience."

The International Program Committee, which will go into operation immediately, will be chaired by Professor Peres. Members of the Committee are Ake Hjertstrand of Sweden, Professor Boneff, Dr. Herrick, Professor Sedov, and Martin Summerfield.

At right, NASA head of international programs, Arnold Frutkin, and to his side Mrs. Frutkin and Dr. and Mrs. Dryden welcome delegates to the NASA reception and buffet. Dr. Frutkin shakes hands with K. I. Gringauz of USSR and prepares to greet Luigi Napolitano, Italy.

Three new voting members were admitted to the Federation—the Mexican Society for Interplanetary Studies, the Cyprus Astronautical Society, and the Romanian Academy of Sciences. In addition, the Portuguese Astronautical Group was selected as the voting member from Portugal. The Federation now has 43 member Societies representing 34 different countries.

The IAF International Academy of Astronautics announced at the meeting that it had taken over publication of the multilingual glossary of astronautical terminology from the IAF Documentation Committee. The glossary, containing some 6000 terms in six different languages—English, French, German, Italian, Russian, and Spanish—will be printed by the publishing house of the Czech

Delegates and attendees enjoy excellent viands in a cheerful atmosphere at the Congress banquet Thursday evening. The banquet was preceded by a reception sponsored by the GE Missile and Space Vehicle Dept.

Congressman James G. Fulton, second from left, member of the House Committee on Science and Astronautics, looks in on the IAF proceedings. Discussing goings-on with him, from left, Martin Summerfield, who moderated combustion panels at the meeting, John Cobb Cooper, president of the International Institute of Space Law, and Howard Seifert, a retiring IAF vice-president.

Academy of Sciences, and is expected to be available in 1963 or 1964.

The IAF Tracking Committee was disbanded at the meeting, in accordance with a proposal by its chairman, Professor Tabanera, who noted that, with the establishment of a worldwide tracking network, amateur tracking was no longer required.

The International Affairs Committee reported that the IAF now has a status with the UN, UNESCO, and the ITU equal to that of any nongovernmental organization, and a resolution was unanimously approved expressing the Federation's appreciation for UNESCO grants to young scientists and a grant for a study group which met in Paris last month to discuss plans for an International Man-in-Space Symposium to be jointly sponsored by the IAF, the Academy of Astronautics, and UNESCO.

The Finance Committee reported that the financial position of the IAF is relatively sound, and no changes were made in the dues structure for the coming year.

Meetings of the Academy of Astronautics and the International Institute of Space Law were also held during the Congress (see page 55).

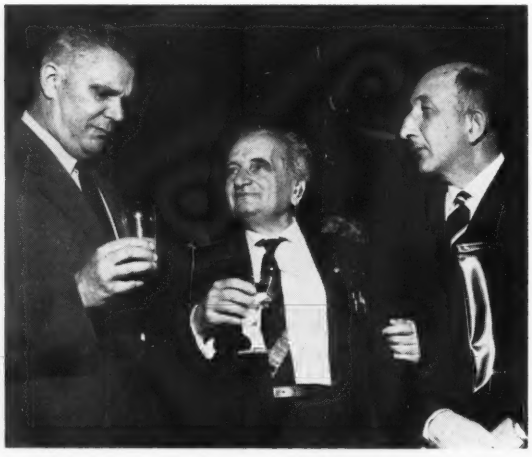
The opening ceremony, held at the Smithsonian Institution, was highlighted by an address by Hugh L. Dryden, NASA deputy administrator, who welcomed delegates to the Congress, and by the remarks of President Sedov. The possibility of future cooperation between the U.S. and the USSR on space projects was discussed by both Dr. Dryden and Professor Sedov in an an unscheduled question-and-answer period during the ceremony.

The Congress included the usual round of social activities, getting underway with a mixer arranged by the ARS National Capital Section and continuing with receptions sponsored by the Air Force and NASA; a luncheon meeting of the National Capital Section which was addressed by ITU Secretary-General Gerald C. Gross; a private tour of the National Gallery of Art with music supplied by the AF Strolling Strings ensemble; a memorable boat trip along the Potomac to Mount Vernon, continuing the Congress tradition of such trips; and, of course, the annual banquet, preceded by a reception sponsored by GE-MSVD. Washington earned its reputation for good food on these occasions.

Foreign visitors also had an opportunity to visit NASA's Goddard Space Flight Center on the day following the meeting.

The 300 ladies who attended the Congress were treated to a special program organized by Mrs. Samuel Herrick and Mrs. Herbert Friedman which included bus tours of Washington, special tours of the Capital and the White House, a tea, and luncheons and visits to private homes.

A number of ARS and AAS members in the Washington area acted as hosts for foreign visitors



Sometimes, you feel space and time. From left, R. Pesek of Czechoslovakia, T. von Karman, and A. Vannucci of France at a reception.

The Hon. Gerald C. Gross, secretary-general of the ITU, discusses "The International Telecommunication Union and Space Communications" at a luncheon meeting of the ARS National Capital Section midweek. Seated to his left, Andrew Haley, IAF and ARS general counsel, and Prof. Sedov, head of the USSR Academy of Science's Interplanetary Communications Commission and retiring president of the IAF after two terms in office.

during the week of the Congress. The foreign attendance, sparked by a special charter plane organized by the Swedish Interplanetary Society, was larger than had been anticipated, and happily so.

More than half of the papers presented at the Congress were U.S. contributions. A number of these gave good, informative surveys of this country's plans and developments in power systems, advanced communications, combustion research, deep-space radar and radio-telescope experimentation, nuclear-propulsion programming, space-probe instrumentation, materials in space, and human factors. Many of these papers made it clear where foreign scientists and engineers might contribute to space science and technology.

The Russian delegation, headed by Professor Sedov, presented nine papers, none having to do with USSR development programs directly.

The Russian papers were received with interest, especially the report on the Moscow Institute of Electrical Engineering's Venus radar bounce experiment by V. A. Kotelnikov and the paper by Lt. Col. O. G. Gazenko and Col. V. I. Yazdovsky on Cosmonaut Gherman Titov's reactions to weightlessness ("Some Results of Physiological Reactions to Space Flight Conditions"), presented by Col. Yazdovsky, who is an associate of the USSR Academy of Medical Sciences.

The Kotelnikov report was made during a marathon, all-day session midweek on exploration of the solar system by radar and radio astronomy, chaired by Herbert Friedman of NRL. This session covered measurements on the moon, Venus, Jupiter, Mercury, and the Sun, plus a report on the NRRS 600-ft radio telescope now under construction, and numerous formally scheduled comments from the floor.

The various data—radar and radiometric—presented from recent lunar studies did not lead to new conclusions about the moon's surface or structure. Z. Kopal of Manchester Univ. commented that radiation, rather than conduction, may be considered in interpreting surface temperature and heat transfer, and gave the opinion that it is too early to predict a structured lunar surface. Ernst Opik, now at Maryland Univ., concluded that results presented "gave no relevant answer" to the question of dust thickness on the lunar surface. His colleague S. F. Singer remarked that calculations show that lunar dust cannot be fluid in terms of an electrostatic transport mechanism, as had been suggested by Thomas Gold. B. S. Yaplee of NRL mentioned that a new radar technique gives earth-moon distance in terms of the velocity of light, and measurements need no longer be made in terms of an equatorial line. NASA's John P. Hagan called attention to the need for a lunar orbiter to determine, among other things, the diameter of the moon exactly.

Dr. Kotelnikov's report (CONTINUED ON PAGE 124)

J. C. Peres of France, newly elected president of the IAF.

20,000th ARS member

Membership is urged to pitch in in drive to double the size of the ARS by year-end, and increase Society's effectiveness

By Abe M. Zarem

CHAIRMAN, ARS MEMBERSHIP COMMITTEE

The 20,000th member is Lovick Osteen Hayman Jr. a 25 year old aerospace technologist at the NASA Langley Research Center in Virginia. Mr. Hayman, whose specialty is fluid mechanics, received his Bachelor of Aeronautical Engineering at Georgia Institute of Technology and is currently working toward his Masters at Virginia Polytechnic Institute. Mr. Hayman is also a member of the Institute of Aerospace Sciences.

THIS fall the American Rocket Society undertook an ambitious membership expansion, the ultimate goal of which was to double the size of the Society by the end of 1961. At the time the drive had started, ARS had 18,500 members. After the Space Flight Report to the Nation in October, ARS had reached another notable membership milestone, receiving the application of its 20,000th member, a short profile of whom appears in the panel on this page. However, this is far far from attainment of that ambitious goal that could be so easily reached if only every member of the Society would take it upon himself to sign up one additional member. Many conscientious members of the Society have already signed up two, three, or four additional members, but it has not been enough, and it cannot be unless all members of the Society do likewise.

Fears and criticisms have been expressed by some to the effect that an all-out membership drive by the ARS is unseemly and undignified; by others that size alone is not important; and by still others that truly effective work can only be done by a relatively small organization. We do not feel that it is unseemly or undignified to make an earnest attempt to persuade competent engineers and scientists, actively and professionally engaged in the U.S. space program, to become members of the American Rocket Society, an organization uniquely dedicated to their primary professional interest. One should realize the aim of the drive is not numbers alone, but effectiveness in serving the membership and achieving the aims and purposes of the Society.

ARS is not engaging in an all-out membership drive just so that it can be numerically large and claim an enormous membership. A series of surveys have shown that despite its dramatic increase in membership the quality of membership has maintained an equally dramatic rise. Today the percentage of advanced degrees held by members is significantly higher than it was one year ago and the percentage of members who act in a supervisory or managerial capacity is also substantially higher than a year ago. The quality of articles in the ARS publications and of papers at specialists' conferences is also higher than a year ago. Thus, along with a steady numerical growth, the Society has managed by its very nature to maintain an equally great rate in increase of quality.

In the September editorial in *Astronautics*, the groundwork for this membership drive was laid. In October a mailing was made to each member of the Society, urging his participation and enclosing membership blanks and reference forms to be attached to them. To date, a number of these have been returned, but it is evident that the largest portion of them have not been used at all.

It is exceedingly important that every member of the ARS understand the purpose of the Society and participate in its growth. The true meaning and significance of our space program must be clearly understood throughout the country and the name of the American Rocket Society must be made synonymous with these objectives. To successfully attain these goals it is essential that the ARS possess a large and vital membership. The acquisition of that membership is your responsibility. ♦♦

Board revises membership procedures

Senior Members will be appointed effective January 1 . . . Membership for one year in ARS will be required for Senior Members . . . Separate membership applications for different grades discarded

By Abe M. Zarem

CHAIRMAN, ARS MEMBERSHIP COMMITTEE

THE new ARS membership grade structure established last summer was revised by the Society's Board of Directors at its meeting at the Space Flight Report to the Nation in New York in October. The revisions approved by the Board, primarily affecting the new Senior Member grade, will become effective the first of the year, and are expected to answer criticism and misunderstanding of the original plan.

Since the publication of the original list of Senior Members and announcement of the creation of a new Senior Member grade, there has been considerable misunderstanding and criticism not only of the grade itself, but of the method in which it was initiated, established, and administrated. The ARS Board, the Membership Committee, and the Headquarters staff have been and are quite concerned by this criticism; and, as a consequence, they undertook immediately to revise the requirements and procedures in such a way as to respond to the criticisms and apparent desires of the ARS membership with regard to the Senior Member grade.

The changes made by the Board are as follows:

1. Beginning January 1, there will be only two types of membership application forms. The student application will remain the same. For all professional grades, however, there will be just one application form, which will not indicate the grade desired by the applicant. Henceforth, applications will be merely for membership in the Society, and grades of Associate Member or Member will be assigned to all professional applicants at the completion of normal processing by the Membership Committee.

2. Beginning January 1, an additional qualification for Senior Member grade will be that the candidate must have been an ARS member for a minimum of one year. In addition, a nomination and appointment procedure has been established for the Senior Member grade. Senior Member nominations may be made by the ARS Board, the Membership Committee, ARS Technical Committee chairmen, ARS Fellows, and ARS Section presidents. Section presidents may make such nominations only in response to a request by the ARS Membership Committee or the Section's membership Committee or the Section's membership committee chairman.

The nominators will be entirely responsible for gathering and transmitting the justifying and supporting evidence of professional capability, competence, and achievement and appropriate reference information. The nominations will be periodically reviewed and approved or disapproved by the ARS Membership Committee. The chairman of the Membership Committee, on behalf of the Board of Directors and Fellow Members, will then notify the successful candidates of their elevation to the grade of Senior Member.

3. Until January 1, all membership applications will continue to be processed and graded in accordance with the procedures established July 1.

Uniform Application Procedure

From a practical point of view, the effect of these revisions will be as follows: Only students may apply for a specific grade. All professional members will apply only for ARS membership, and a grade of Associate Member or Member will be assigned to each applicant by the Membership Committee. It will not be possible to apply for the grade of Senior Member or Fellow Member, and those grades will be by nomination and appointment only. Qualifications for the various grades will remain the same, except for the additional Senior Member requirement of one-year's membership. At least two of three references required for professional-grade applicants will still have to be ARS members. (CONTINUED ON PAGE 89)

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Structures and Materials

(CONTINUED FROM PAGE 53)

choice of an optimum for a given design is possible. Scala's result that the oxidation of graphite proceeds at a slow rate is encouraging for application to leading edges for manned reentry vehicles. More-passive thermal protection systems, which depend to the maximum on thermal re-radiation, still await higher temperature capability materials and more-oxidation-resistant coatings than are now available, although the chromium alloy of Scruggs already mentioned approaches the desired characteristics. Also still to be desired is a high-temperature, light-weight fabric material suitable for the construction of a Rogallo paraglider re-entry aid.

"Flimsy" Structures for Space Erection. Prime contributions to the design and analysis of membrane-like structures have been made this year at the NASA Langley Research Center. Progress toward the rigidization of such structures in space by reinforcing them with plastic foams was reported by Hefty, et al. at the ARS Space Flight Report to the Nation; and the "isotensoid" pressure-vessel concept introduced by Schuerch at the Santa Barbara meeting last year was carried on by Zichel, again as reported at the SFRN. The isotensoid concept is an excellent example of the integration of structures and materials; here the structural form is especially tailored to the optimum utilization of the properties of filamentary materials.

Shell Theory. As if the analytical problems associated with shell theory were not difficult enough in simple, idealized cases, this year they continued to be extended into the more complex problem areas. Gerard considered theories of plasticity for orthotropic cylinders; Seide, the stability of cylinders with an elastic supporting medium; and Johns and Orange, the stresses and deflections of a wide variety of shell configurations. In all cases, the state of knowledge and the usefulness for engineering application has been enhanced. Dynamic response of shells—a problem of vital concern in booster design—received a great deal of attention, with emphasis on the experimental approach. First results of model vibration tests of the Saturn were achieved by the NASA. First dynamic-load measurements in flights of large boosters were also reported. Data from tests of acoustical excitation and from fuel-sloshing experiments have advanced the state of knowledge of the actual response of vehicle structures. Boost-vehicle material developments during the year showed some continuation, but no acceleration, of the trend toward filament-wound composites, one interesting variation being filament winding superposed on an aluminum liner, as described in Mayer's SFRN paper. Another paper at the SFRN gives a clue to a reason why filamentary rocket-motor cases have not made more spectacular progress; in this paper Siuta and Wolff described some of the problems associated with the reinforced plastic materials.

Fatigue. An interesting extension of the work of Coffin and others to provide some rationale for the "prediction" of S-N curves has been made by Manson and his co-workers at the NASA Lewis Research Center. Not unreasonable correlations of prediction and experiment have been achieved for a number of materials with their method of relating total strain range of the material to cyclic life. Perhaps even more important in the long run than these results, however, is that these successes in relating fatigue strengths to other mechanical properties may stimulate progress toward deeper understanding of deformation and fracture mechanics in general.

Landing. The use of both structural deformations and the yielding and fracture of materials to absorb landing impact has emerged as a prominent development. Energy absorption by the impact buckling of cylindrical shells has been shown by Coppa to have high efficiency on a weight basis for impact velocities below 100 fps, particularly if the resultant acceleration transmitted to the protected object must be kept low. Energy absorption by the fracturing of high strength-to-weight ratio materials has likewise been shown by Fisher to have a high efficiency. An over-all assessment of the utility of various approaches to impact absorption was given by Esgar in his lecture at the SFRN. The importance of efficient impact absorption to the soft lunar landing is clear; efficient shock absorbers will also contribute in all docking maneuvers in rendezvous, and continued developments of structures and materials in this area may be of prime significance.

Radiation Shielding. Recent developments in studies of shielding from energetic particles have concentrated upon the determination of dosages resulting from secondary radiation produced in stopping the primary particles. For example, Keller and others have shown that the thicker the shield, the greater the proportion of dosage due to secondaries, and for shield thicknesses greater than about 40 gm/cm^2 the secondary radiation is of prime importance. Experimental con-

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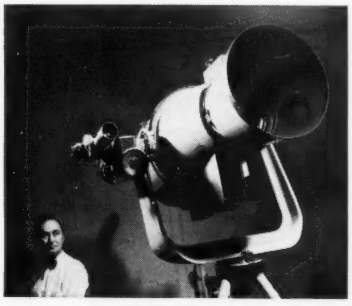

We have built a few of these infrared scanning heads. They are well liked. More could be built if need be. A new one could be identical with this model or considerably modified. The trouble with manufacturing this type of merchandise is that it seldom results in nice long production runs. The American genius needs nice long production runs to express itself.

This scanner contains a line of 50 gas-discharge lamps that wink in correspondence to infrared radiation imaged by a 10-inch-aperture *f*/0.76 Schmidt system on a 50-element linear array of Kodak Ektron Detectors. While the image is oscillated across the line of detectors, the line of lamps is effectively swept in synchronism across the visual field of the beholder. He sees a picture of a 20° chunk of the infrared environment for search and track of objects differing in temperature from the background by a number of degrees that is determined by which of several types of interchangeable detector arrays happens to be in place. The instrument is also useful in another mode of operation with multichannel oscillographs for radiometry of faraway warm spots.

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Anybody who draws the obvious conclusion has failed fully to engage his brain cells in thought. The answer to the question depends on the sensitivity of the film. Once that is known, one can say how much of a dose the worker has probably had less than.

Social ethics in advanced countries require the assumption that the worker has actually *had* that much radiation. This is known as the "administrative" dose. Records are kept as in a bank. When administrative and physical doses add up to a critical figure, the worker is shifted to a different job. He may habitually spend every Saturday night cruising the center line of a busy highway at 80 m.p.h. Nevertheless, the critical figure assumes that he wants to live forever and become the progenitor of an infinite line of biologically perfect descendants. Pressure to squeeze it down will never let up, we hope.

Without relaxation of solicitude, we have taken steps to cut down the waste of his job experience. By reducing the administrative dose (which is the only kind of radiation dose he really ought ever to get on the job), we can keep him in his slot longer. It is within our power. All we have to do is make more sensitive film. This we have now done. It is called *Kodak Personal Monitoring Film, Type 3.*

The packet it comes in also includes a piece of low-sensitivity film. Its sensitivity is so low that it can measure 1800 roentgens, a horrible thought. The lower limit of dose measurement for the high-sensitivity film in the packet runs somewhere below 10 milliroentgens. The vague phrasing of that statement doesn't mean that the exact value is unimportant. The main point of this discussion is the importance of the figure. It's just that its precise determination depends on such a complexity of factors that we won't try to explain it here.

If interested, prepare yourself by studying pp. 10-53 to 10-75 of Radiation Hygiene Handbook *(McGraw-Hill Book Company, Inc., 1959). Then bring your knowledge up to date by requesting a data sheet on* Kodak Personal Monitoring Film, Type 3 *from Eastman Kodak Company, Special Sensitized Products Division, Rochester 4, N. Y. Be impressed with the fact that the boys who built this film have just finished measuring the dose to which a recent Discoverer satellite exposed itself in its travels. It's no administrative dose.*

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firmation of the calculations, particularly as regards biological effectiveness, are still needed, together with an analysis relating the results to the corresponding damage to man from cosmic radiation for long space flights.

Active shielding took a giant step forward, at least in concept, with the Bell Telephone Laboratories announcement of the successful achievement of superconductivity in Nb_3Sn, both in intense magnetic fields and with high current densities. The use of an electromagnetic dipole field employing such superconductivity was investigated by Levy with encouraging over-all results in terms of system weight.

Real progress toward the solution of the solar-flare shielding problem must await a better definition of the directionality of solar-flare particles and of the practical utility of superconductivity in the coil sizes required, or of the possibilities of high electrostatic voltages with the large electrodes needed to deflect energetic particles in space.

Meteoroid Impact. The development hoped for of an experimental facility capable of accelerating specimens to meteoroid velocities has still not been achieved, although rumors persist of a new technique with promise of reaching 60,000-fps impact velocities. Handicapped by the lack of experimental data, investigators still have advanced the state of knowledge in this area. Eichelberger and Gehring developed a model descriptive of hypervelocity penetration as confirmed by nicely run experiments at velocities in the 20,000- to 30,000-fps range. Differences of opinion still exist, however, regarding theories of cratering, and particularly of the effectiveness of the multilayer meteoroid-bumper concept. Next year should see some resolution of these differences through the development of the desired ground facility or from the results of the flight experiments planned, particularly the S-55 satellites to be launched with the Scout booster. Final resolution of the problem, however, will still probably await the actual recovery of flight vehicles which have encountered real meteoroid impacts, so that the true damage can be evaluated.

Materials in Space Environment. Research continues on the interaction of the environment of space and materials useful for space-vehicle construction. A comprehensive status report of knowledge in this area was presented in the paper by Jaffe and Rittenhouse at the SFRN. In general, the results are encouraging—to the extent that sublimation of most materials in vacuo is negligible, erosion by meteorites and sputtering is generally not serious, and a number of lubricants appear suitable for sliding surfaces. On the other hand, radiation damage must be considered for sensitive materials in the radiation belts, and penetration or internal spallation may be caused by collision with sizable meteoroids. The meteoroid problem, as noted before, is still with us.

Despite the lack of sensational developments, 1961 can probably be rated on the whole as a successful one for structures and materials technology. This rating is perhaps conditional, for it depends in large measure on whether the promises inherent in the work mentioned here are soon realized. Memories of past failures to achieve potentials—for example, the slow, disappointing development of beryllium—have led to the recognition of the need for a unified approach to problems by the structures and materials technologies. It is an increasing cooperation in this area that leads me to the optimistic conclusion that the potentials discovered in 1961 will soon be reached.

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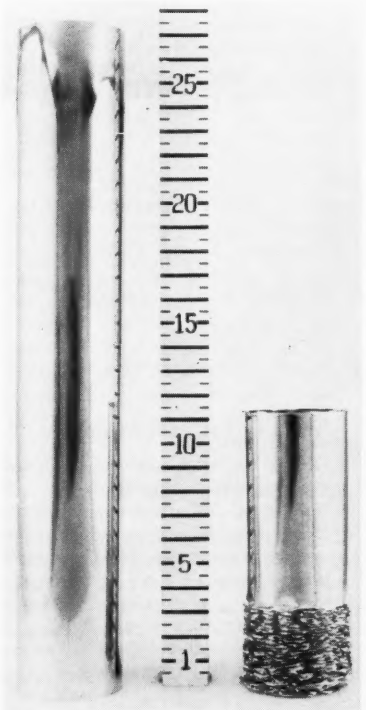

Energy absorption by impact buckling of a thin-walled cylindrical shell, illustrated here, has emerged as an important element in space-vehicle-landing studies.

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Scientists and engineers at General Dynamics | Astronautics worked constantly at the most advanced state of the various arts involved. Boldly, they introduced and proved entirely new concepts of rocketry, and in record time they developed the Atlas.

The same depth of imagination and technical daring is now at work modifying and adapting this sophisticated machine for a variety of civilian and military space missions. Dozens of specialized orbiting and interplanetary vehicles will depend upon the power of Atlas to thrust them into space.

These programs reach far into the future and require the skills of highly resourceful engineers and scientists in many technical disciplines.

Atlas is the free world's first intercontinental ballistic missile; the first missile to travel more than 9,000 miles across the earth's surface; the only one to lift itself into orbit. Atlas marked the first use of swivel engines for directional control and it was the first to use airframe skin as fuel cells.

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You'll find most of the details on this and the following page, plus a convenient inquiry card. If the card has been removed, or if you wish to furnish or request more detailed information, write to Mr. R. M. Smith, Industrial Relations Administrator - Engineering, Dept. 130-90, General Dynamics | Astronautics, 5710 Kearny Villa Road, San Diego 12, California. (If you live in the New York area, it may be more convenient to contact Mr. T. Cozine or Mr. E. Hart, General Dynamics | Astronautics, 1 Rockefeller Plaza, New York City, Telephone CIrcle 5-5034.)

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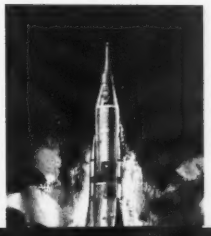

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ELECTRICAL ENGINEERING ☐
ELECTRONIC ENGINEERING ☐
CIVIL ENGINEERING ☐
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Test, Operations, and Support

(CONTINUED FROM PAGE 53)

A closer look at some of these accomplishments and comments on the implications of future requirements on test, operations, and support activities may be of interest.

Static Testing. In static testing, several significant milestones were realized in 1961. Testing of the $1^1/_2$-million-lb-thrust F-1 engine was initiated with the activation of Test Stand 1-A at the Edwards AFB rocket site. By October, the last of three programmed engine positions was activated. It is planned that this complex be able to handle 60 engine tests of the F-1 size per month by early 1962.

At Marshall SFC the static testing of the first Saturn C-1 booster cluster was completed on the modified Jupiter static stand; and a dynamic test stand was activated there to obtain essential information on the dynamic behavior of the Saturn vehicle and its stages in full-scale configuration. The structural integrity of the C-1 assembly was confirmed by vibration tests in this 204-ft structure before release of the vehicle for launch.

In addition, site and foundation work have been initiated on a Saturn static-test facility at MSFC that will provide facilities for the preparation, handling, and static test firing of booster assemblies utilizing clusters of H-1 or F-1 engines. It is estimated this new facility will cost approximately $15 million.

Construction of the first "down-firing" nuclear-rocket-engine test facility began in June 1961 at the AEC's Nevada Test Site. Completion of the test complex, called Engine Test Stand 1 (Test Cell "D"), will usher in a new era of rocket-engine testing in which the reactor-engine assembly is transported, installed, tested, and removed from the test stand by remote-controlled equipment.

The facility incorporates extensive shielding, both fixed and movable, to protect personnel and to reduce nuclear activation of the test-stand structure. In addition, for structural and nonstructural applications, various aluminum alloys have been widely used. These mainly lead to radioactive isotopes of short half-lives.

Launch Facilities. Launch facilities and capabilities, particularly at Cape Canaveral, have seen marked expansion in 1961. Saturn Launch Complex 34 was completed and exists today as the largest known launching site in the world and the first built especially for the peaceful exploration of space. It is the latest evolution of the traditional launch concept. The total complex cost, exclusive of land, has been reported to be approximately $45 million. The installation is dominated by a movable structure 310 ft high weighing over $5^1/_2$-million lb. In spite of its size this structure can be controlled by a single operator and is capable of moving at rates of from $1^1/_2$ to 40 ft per min.

Designed along new concepts is Saturn Launch Complex 37, which will provide a separate four-bay assembly building, transportable launchers (complete with umbilical towers), an arming tower, fueling facility, and minimum pad. All assembly and checkout operations will be performed in the assembly building, minimizing time on the launch pad proper to permit higher launch rates and greater facility utilization. The projected cost of Complex 37 is $190 million. However, 32 launchings per year are considered possible, a rate which would require eight conventional complexes at a total cost of $360 million, or an estimated saving in facility cost of $170 million. The service structure for this complex surpasses all of its predecessors, having a basic height, including derrick mast, of 375 ft and an estimated basic-structure weight of 7-million lb. Site preparation is now underway for Complex 37.

Launch and Range Operations. In 1961 launch operations had its most active year. The Mercury and Discoverer launch and recovery programs provided opportunities for land, sea, and air logistics and coordination. Again this year there was a substantial increase in the number of large missiles and vehicles launched. (This is shown in the Space Box Score on page 78.)

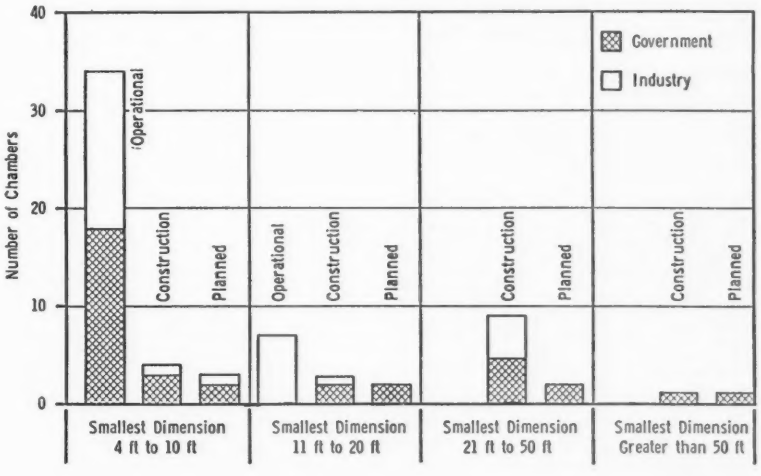
A significant reliability record has been reached in the past 12 months in the launchings of our strategic missiles for research and development programs and in the support of space experiments. In these launchings the Atlas missile has shown approximately 80% reliability and the Thor above 90%. The last 11 firings of the Titan in 1961 resulted in 10 complete successes and one partial success. Checkout and support operations played a significant role in this effort.

Polaris Pushed Art

In the Navy's highly successful Polaris program, a "fourth dimension" of launch environment was introduced. The submerged submarine severely strained the state of the art for support and conduct of tests. Standard operating procedures were not applicable; new procedures and techniques were developed. The complete enclosure of the missile in a steel launch tube in the steel hull of the submarine imposed problems of RF checkout to meet range-safety requirements. The underwater launch — dictating prescribed depth, velocity, and heading of the submarine properly geared to a precise launch time (T-time) — imposed further problems. The limited number of underwater telephone and radio channels complicated vital communications so essential to any test operation. And finally, logistics support had to be developed precisely to prevent delays or cancellations due to lack of spare parts or a ready capability to troubleshoot. The over-all Polaris system is designed with the capability of firing the complete complement of missiles from a single submarine in relatively rapid succession.

U.S. Space Simulation Chambers

Of 4-ft diam and larger having pressures lower than 1×10^{-5} mm Hg.



In 1961 steps were taken to evaluate this capability. The degree of success achieved in the solutions of the problems introduced by the submarine launch is a tribute to personnel of the Atlantic Missile Range, participating contractors, and the Navy.

In the field of range instrumentation, the Mistram Interferometric Tracking System, presently under construction and planned for operation at Cape Canaveral in 1962, is expected to provide measurements of the position and velocity vectors of a space vehicle to accuracies of range error to 0.4 ft and range-rate error to 0.02 fps. These accuracies are to be obtained on vehicles having range velocities up to 50,000 fps and at ranges up to 1000 n. mi.

New Tracking Skill

Another new range instrumentation development, the FPQ-6 Radar Precision Pulse Tracking System, has been designed to meet the ever-increasing needs of the test ranges for accurate position data at increasing distances on targets of small cross section. The AN/FPQ-6 will have a skin-track capability of 300 n. mi., a range of 5000 m. mi., and an angular accuracy of $^1/_2$ mi. The corresponding values for the presently employed AN/FPS-16 are 200 n. mi., 500 n. mi., and 1 mi., respectively. The AN/FPQ-6 will be operational in 1962.

Costs estimated at $70 million are being expended to convert Mars C-4-type ships to Mobile Tracking Stations. These facilities will be essential to obtain trajectory data when space vehicles transfer from parking orbits to new orbits. They will be completely equipped with C-, X-, and L-band radars, advanced communication systems, telemetry receiving and recording equipment, stabilization and navigation equipment, data-handling and display systems, infrared trackers, and meteorological equipment. The operational date for the first ship is in the fall of 1962.

The complexity of our new large systems has increased the time devoted to checkout. This problem has received serious attention. During the past year, automatic checkout equipment for use in the factory checkout of the Saturn S-1 stage was designed and is under development by MSFC. The complexity of the Saturn first stage with its eight large liquid engines, and the research and development nature of the first vehicles, which will be flown this year, require an appreciable advancement in checkout equipment. The computer will program the checkout operation and permit increased reliability and greater accuracy. In addition, reliability statistics will be increased in quantity and consistency.

A significant step taken in 1961 was the adoption of the "concurrency concept" by the Aerospace Systems Command of the Air Force for the testing and evaluation of the Minuteman missile. The complete missile system, with the exception of the silo, was evaluated during the first launch in March 1961. This was a radical departure from the typical testing of a multistage vehicle, where limited tests are made of the first stage, then limited tests involving a nonpropulsive second stage to test out the staging effects, etc. Acceptance of this "concurrency concept" is based on the assumptions that the rocket engines have been well tested and that the only item not tested in its true environment is the guidance package. To a large measure, the economics of a missile or space-vehicle program will dictate the advisability of adopting this concept. As systems increase in size, the costs associated with sequential development may well justify the calculated risks of this alternate approach.

Space Simulation. During the last few years, simulated altitude and space environmental testing of missile and space-vehicle components, particularly rocket-propulsion systems, has become generally accepted as a valuable checkout step between sea-level testing and actual launch. Today, testing techniques employed in these simulated high-altitude facilities have progressed such that, on a routine basis, altitudes of 140,000 ft, corresponding to 0.03 psi pressure, can be maintained during steady-state long-duration testing. This progress was made possible mainly by systematic research in the diffuser injector field, including such advanced concepts as conical adjustable inlets, boundary-layer suction, exhaust-gas cooling, and second-throat supersonic diffusers. These high-altitude facilities have been of great value in determining nozzle altitude performance on rocket engines and base-recirculation characteristics on multichamber or clustered propulsion systems. Many design deficiencies can be identified and corrected prior to actual launch, thereby reducing operational failures and accelerating flight programs.

As to high-vacuum space chambers, much basic information on radiation, temperature variations, and meteorite bombardment is still needed to establish specifications for accurate simulation of all parameters. However, a significant number of basic chambers capable of high vacuum and designed to ultimately accommodate equipment to produce associated environments are already in use or under construction. A chart on page 69 shows number of chambers operational, in construction, or planned by government and industry by categories, with minimum dimensions of 4 ft to greater than 50 ft—a total of over 50 chambers.

Space-environment facilities will become increasingly important, particularly for components and subsystems, as developments proceed on operating space systems. Careful thought

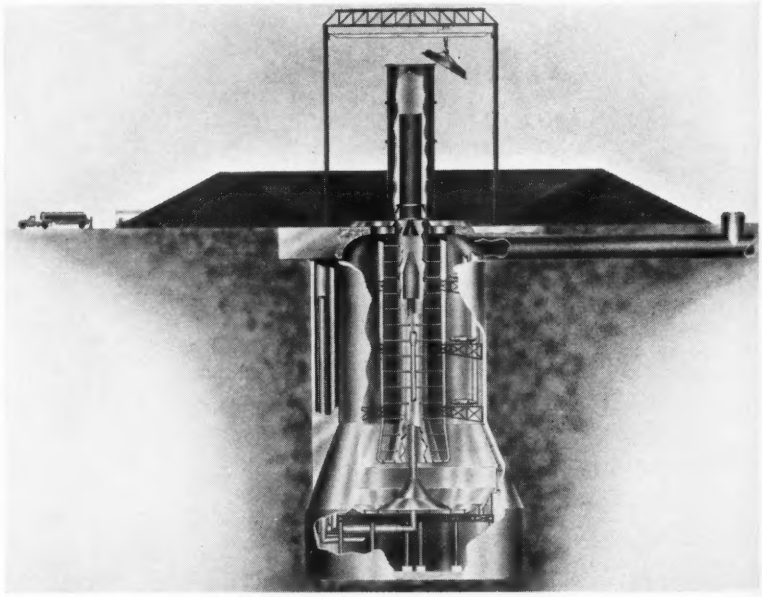


Illustration of high-altitude test cell for rockets up to 1.5-million-lb thrust under construction at Arnold Engineering Development Center, Tullahoma, Tenn.

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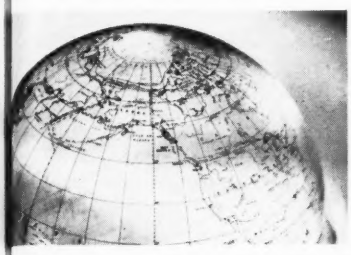

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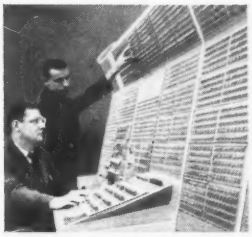
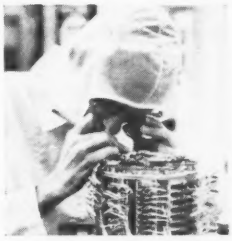


SATIN • C
PPLY SIMULATION
ARPAT • F
LDATA/INFORMER
MIDAS • I
SSILE TEST DATA HANDLING



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should continuously be given to the real need of space simulation for complete systems. It may very well develop that direct testing in space may be less costly than simulation.

Future Requirements

Support and Instrumentation. In spite of the commendable showing of support operations, new developments and improved technology in airborne equipment have pushed ground-support systems to the absolute limit of the state of the art. Increases in vehicle velocities and instrument target range, paralleling the higher velocities and the tightening of velocity-measurement accuracy requirements, have contributed to this range-instrumentation problem. Inertial-guidance systems have now become so accurate and operate over such long ranges that ground-based electronic trajectory-measuring systems have reached the point where signal transmission times now contribute a significant portion of the total system error.

Since it is not likely that these times can be reduced further, other approaches will have to be taken to obtain more accurate trajectory data. For example, some missile and/or satellite flights may have to be scheduled for the purpose of tracking-system calibration alone. In addition, ballistic cameras with larger lenses will be required to obtain the resolution necessary for calibration, and these are already equal to the lenses of a good astronomical telescope. To achieve the necessary accuracy in positioning of the antennas on the ground, consideration will have to be given to such variables as diurnal temperature variations, wind loads, and the movement of the earth's crust with the tides.

On another front, the ground equipment to support the more sophisticated space and missile systems now exceeds in complexity the systems themselves. This is a double-edged sword. On the one hand, checkout and maintenance of these equipments are often more difficult than for the system itself. Yet, if we are to achieve reasonable launch rates without tying up more billions of dollars in redundant launch facilities, we must accomplish this checkout in less time than we did on the earlier, simpler systems.

The requirement to speed up launch operations will become acute and will require solution as rendezvous operations in space are undertaken. Extremely small launch windows are necessary for such operations, and present procedures for checkout and servicing immediately prior to launch will have to be modified. Planned improvements in launch-pad time from six weeks to six days will ultimately have to be further reduced to hours and minutes.

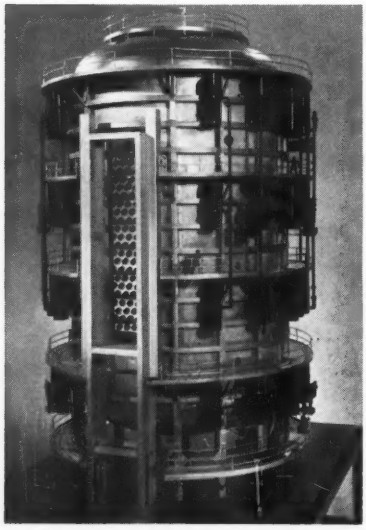
The advent of the nuclear rocket will present a challenge in the development of remote-handling equipment and procedures if the desired progress in this important development is to be realized.

The lunar program has stimulated completely new philosophies in the checkout and support area. Here, definitely, the support and operations engineers will be required to work very closely with the component, subsystem and vehicle-system designers. Minimum complexity, maximum reliability, fully automatic, lightweight, minimum-size checkout and support systems will be required to keep increasingly complex vehicle systems operational if the goal for the 1960s is to be realized.

Handling and Launch. It should be probably accepted that we have reached a threshold when a new series of facilities will have to be built to handle an increasing number of much larger vehicles. We can, in fact, be fairly certain that today's Saturns are but the forerunners of Novas and even larger units. (An order-of-magnitude increase in weight and thrust level can be anticipated.) One can visualize increases in the maximum heights and diameters of complete assemblies to twice those now being seriously considered. Such vehicles could certainly be considered, and it is well to keep in mind that, although such sizes seem large when extrapolating from our past rocket experience, they are not excessive in comparison with today's naval vessels.

Such vehicles, however, would be completely beyond the capabilities of all existing or planned static-test or launch facilities, and it will represent a real challenge to our ingenuity to examine new approaches for their launching, fabricating, and transporting. Water transportation and launch appear to offer solutions of many of the problems which will be associated with these large vehicles. In addition, water-based operations will be suitable for achieving the isolation necessary for coping with problems of safety and objectionable noise.

The necessity for large vehicles is believed to exist regardless of the possibilities that are offered by rendezvous operations. Such operations are considered very important. No matter how successful they may be, however, it will always be advantageous to have building blocks as large as possible for space assembly. The rendezvous concept, therefore, should not dampen our enthusiasm to develop facilities capable of handling vehicles of extreme size. ♦♦



Model of 42-ft-in-diam and 82-ft-high space simulation chamber under construction that can produce a pressure level of 10^{-8} mm Hg.

Underwater Propulsion

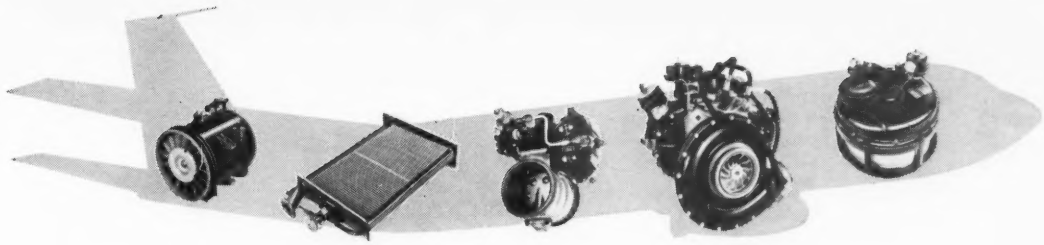
(CONTINUED FROM PAGE 54)

vehicle of superior performance without increase in drag. It is primarily in this area of developing powerplants for higher performance that the papers sponsored by the ARS Underwater Propulsion Committee have focused during the past year—a quest for improved non-nuclear powerplants for underwater propulsion.

Propulsion systems using electric energy are indeed in wide use for various underwater applications. The source of energy is usually an electric storage battery. There are numerous different batteries in use having proven performance characteristics. All work essentially on the same principle, direct conversion of chemical to electrical energy.

Electric battery systems have the obvious advantages that the cycle is independent of depth and that the hardware has been developed to a high degree of reliability. Certain fuel cells theoretically have a potential to exceed the performance of some of the heat engines now in use, but considerable development work remains to be done in this area.

Chemical fuel represents another en-



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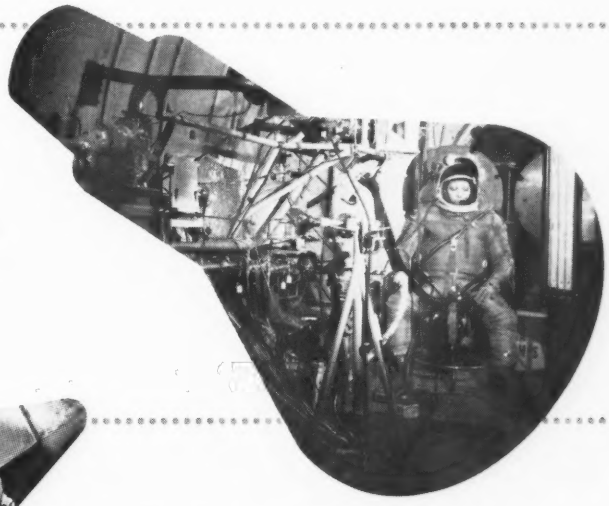

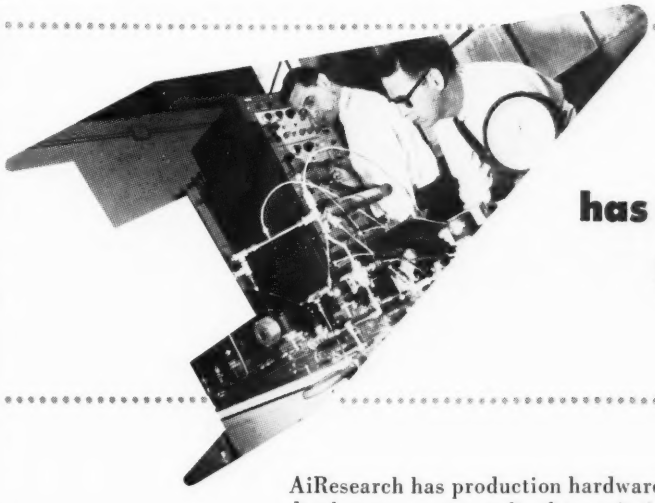

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ergy source for underwater propulsion, and here exists the greatest resemblance between underwater and rocket propulsion. However, propellants which have been used in the past, such as hydrogen peroxide, must be re-evaluated in the light of new requirements. An entire family of chemical energy sources has been reviewed and analyzed for potential use in underwater craft with sophisticated propulsion systems. This family ranges over hydrogen peroxide, hydrocarbon or alcohol fuels with compressed air, solid propellants, liquid propellants with oxidizers, and monopropellants. For all of these chemical systems both fuel and oxidizer must be carried in the underwater vehicle.

In addition, water can be used as an oxidizer as well as a diluent for high performance. In this connection considerable work has been done toward the use of sodium and lithium for underwater propulsion. Means have been developed to handle these metals and mix them with sea water to produce a working fluid of high temperature and pressure which can drive a gas turbine or other prime mover.

If fuel and powerplant constitute a small portion of the total weight of the underwater vehicle, then the most important criterion for evaluation is an energy value in terms of hp-hr/lb, quite similar to other slow-moving transport systems and land-based vehicles. On the other hand, if fuel and propulsion weight constitute a substantial part of the total weight and volume of the underwater vehicle, then the energy value in terms of hp-hr/ft^3 is the more significant value. For underwater propulsion, lithium attains the highest performance on a per-lb basis. For optimum values of energy per ft^3 the use of metals as fuel is significant. Aluminum, zirconium, and magnesium may be considered with sea water as oxidizer and diluent. Theoretical studies in this area indicate potentially great advances in performance; however, considerable development work is yet to be done before such fuels can be used reliably in powerplants for underwater propulsion.

From a theoretical standpoint, the attainment of increased performance potential over conventional chemical powerplants, with lower specific-energy values, indicates that increased performance in terms of speed, power, or range is in the offing. Present powerplants in use resemble more closely existing rocket technology using propellants and oxidants that handle reliably but with low performance.

For Speeds Above 80 Knots

There is an inherent similarity between underwater propulsion systems and propulsion in air except for changes in density, Reynolds number, and friction coefficients resulting for underwater propulsion in relatively large amounts of horespower even at low speeds. For low-speed applications, propellers are the most efficient means of propulsion, just as in air. For high speeds in water—on the order of 80 knots and above—other propulsion systems must be considered, particularly the equivalent of jet engines. For this purpose, both intermittent and steady-state jet engines have been studied, including the hydroturbojet, the hydropulse engine, the water ramjet, the hydrorocket, and the rocket. Just as in air, it can be shown that jet systems offer much greater underwater speeds at the expense of reduced ranges (due to increased total and specific fuel consumption) when compared with rotating powerplants for lower speeds. Nevertheless, the jet systems are free of the problem of propulsor cavitation.

While many studies have been made on various jet systems, today's underwater craft essentially have speeds where more conventional systems are superior in efficiency. Consequently, the thermal systems consist of a gas generator that may resemble a small rocket combustor, where the propellants are mixed with oxidizers and sometimes diluents to produce the working gases. Presently, efforts are being expended to achieve good components. In addition to the gas generator, there is an engine and an exhaust system. Where great variations in depth are to be considered, closed-cycle processes or back-pressure-reducing devices have been proposed. Selection of the right scheme depends on the over-all thermodynamic process. The closed cycle is evidently independent of external conditions at the expense of a condenser and return pump. In other cycles, jet ejectors and jet condensers have been proposed to discharge into the environment. If the exhaust products contain solid particles, as is likely to occur with metal fuels, special devices or processes have to be developed to avoid solid-particle accumulation.

With an electrical energy source, the basic propulsion system consists of an electric motor driving through a shaft and a propeller or impeller to transmit energy into the water. However, the principles of magnetohydrodynamics offer a new potential for electric propulsion, even though it is too early to visualize an MHD system for underwater propulsion in the near future.

Today, underwater propulsion is limited to some military vehicles and a very few oceanographic research vessels. Consequently, the expenditure of talent and money is limited if viewed relative to space programs, and has resulted in developing only the two opposite ends of the entire propulsion spectrum, namely, relatively large vehicles with long duration and relatively small vehicles with short duration. For the latter, many high-performance processes have recently been discussed that offer an increased engineering performance potential. Operational analyses including logistic and financial considerations will decide the future of these processes. ♦♦

Report on the IAA

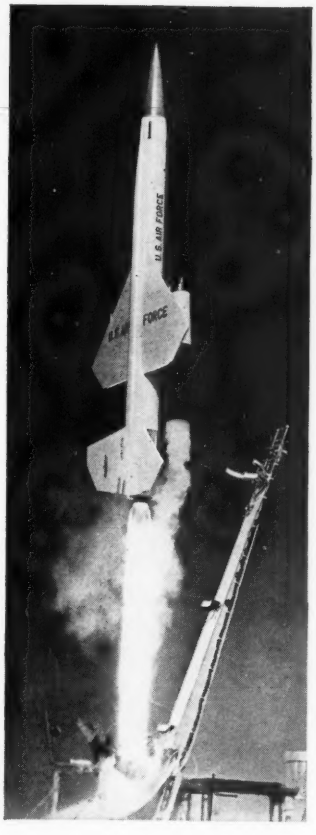
(CONTINUED FROM PAGE 55)

satellites, and dynamics of terminal reentry.

The Academy has been entrusted with the responsibility for the publication of *Astronautica Acta*, so that this international scientific journal has now become the journal of the International Academy of Astronautics of the IAF.

Dr. von Karman pointed out other projects undertaken by the Academy during the past year, such as the preparation of a multilingual dictionary of astronautical terms, a study of the possibility of setting up a manned international laboratory on the moon and the type of research to be undertaken by such a laboratory, and the building up of a specialized library on international cooperation in astronautics. Another of its functions is the organization of symposia at least once a year. During November 1961, an international study group will meet to examine the question of holding a symposium on "Man in Space" late in 1962 or early in 1963. The meeting of the study group is being organized jointly by the IAF, UNESCO, and the Academy.

The Academy also designates the winner of the annual Daniel and Florence Guggenheim International Astronautics Award of $1000. The first recipient was Sir Bernard Lovell, who was presented with the award in recognition of his contribution to the



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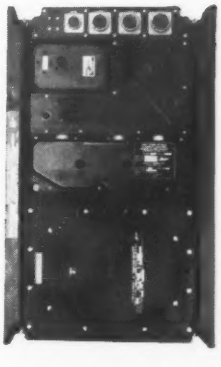

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progress of astronautics through his valuable work with the Jodrell Bank radio telescope. The presentation was made to Sir Lovell at the banquet of the IAF XIIth Congress at the Marriott Twin Bridges Hotel on October 5.

Administrative expenses of the Academy have been covered by a generous three-year grant of $75,000 from the Daniel and Florence Guggenheim Foundation. An appreciable contribution has also been made by the French Government through the French Astronautical Society and the French "Caisse Nationale des Marchés de l'Etat," in the form of offices and facilities provided free of charge for the Academy headquarters at 12 rue de Gramont, Paris. Some of the money made available to the IAF under contract with UNESCO has been earmarked for specific uses by the Academy. Additional revenue sources will have to be found for the coming years if the Academy is to fulfill its purposes and develop its activities.

One of the orders of business at the first regular meeting was the election of officers and trustees. Theodore von Karman (USA) was elected director and F. J. Malina (USA) and J. Peres (France), deputy directors. The following were appointed trustees of their respective Sections: Section 1, Basic Sciences: N. Boneff (Bulgaria), A. Ehmert (German Federal Republic), J. Kaplan (USA), and Sir Bernard Lovell (United Kingdom); Section 2, Engineering Sciences: E. A. Brun (France), A. Eula (Italy), J. M. J. Kooy (Netherlands), and R. Pesek (Czechoslovakia); Section 3, Life Sciences: M. Florkin (Belgium), W. R. Lovelace II (USA), and A. Meyer (German Federal Republic).

The meeting established two new committees, one on the role of the theory of relativity in space science and the other on the history of astronautics. A proposal for a committee to study the question of an international laboratory on Mars was turned over for consideration to the existing Lunar International Laboratory (LIL) Committee.

In regard to the work of the Joint Commission of the Academy and the International Institute of Space Law on technical aspects of space law, the chairman, John Cobb Cooper, reported that it had been decided that studies should be made of the physical characteristics of space around the earth in order to assist the efforts to determine the borderline between air space and outer space from the jurisdictional point of view.

At the plenary session of the membership of the International Institute of Space Law which was held in Washington, D.C., on October 4, 1961, it was decided to change the statutes of the International Institute of Space Law in the following respects: The officers shall consist of a president and secretary, who will be directors serving on a board with 10 other directors. After the statutory changes were made, the nominating committee, consisting of Ernst Fasan (Austria), Jacek Machowski (Poland), and Peter S. Triantafillidis (Greece), submitted their report and the following officers and directors were elected for the ensuing year: John Cobb Cooper, president (USA), Andrew G. Haley, secretary (USA), Antonio Ambrosini (Italy), Luis de Gonzaga Bevilacqua (Brazil), Antonio Franciz Rigalt (Mexico), Cyril Horsford (United Kingdom), Fumio Ikeda (Japan), Vladimir Kopal (Czechoslovakia), Alex Meyer (Germany), P. K. Roy (India and ICAO), Hassan Safavi (Iran), and Michel Smirnoff (Yugoslavia).

Announcement was then made of the Andrew G. Haley Awards. Professor Cooper was awarded the Gold Medal of the Institute for the greatest contributions toward formulation of the rule of law of outer space thus far made during the space age. Professor Cooper recently was elected president of the International Institute of Space Law. The citation making him First Laureate of the Gold Medal designates him as "the father of space law." The presentation of the award to Professor Cooper will take place at a meeting of the Bureau in Paris in the spring.

Smirnoff Honored

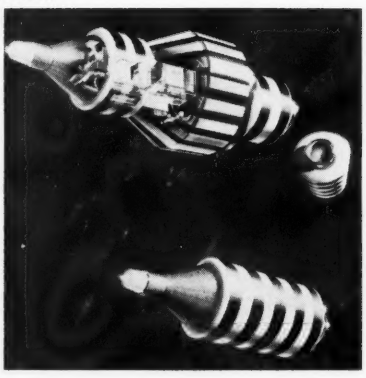
Another prize—in the sum of $500—was awarded to Michel Smirnoff, legal adviser, Foreign Trade Research Instiute, Belgrade, Yugoslavia, and immediate past president of the International Institute of Space Law of the IAF. The citation recites that Dr. Smirnoff is the dean of air law commentators in Eastern Europe and made the most distinguished contributions toward the definition of jurisdiction and sovereignty relating to natural objects in outer space. Dr. Smirnoff is the retiring president of the International Institute of Space Law.

Also, an award of $500 was made to Vladimir Kopal of the Czechoslovak Academy of Sciences, for the most distinguished contribution to the codification of space law and for his major contribution in the drafting of the Constitution of the IAF.

The IVth Colloquium of the Law of Outer Space of the International Institute of Space Law was opened by President Michel Smirnoff on Tuesday morning, October 3. The address of welcome was given by Representative James G. Fulton (R., Pa.), ranking member of the House Committee on Science and Astronautics. The inaugural address, "The Morphology of Justice in the Space Age," was made by Fritz Zwicky of the Carnegie Institution of Washington, D.C., and the California Institute of Technology.

The five sessions of the Colloquium, held on Tuesday and Wednesday, October 3 and 4, were studded with outstanding speakers and subjects. Dr. Smirnoff chaired the opening session on Tuesday morning. Ernst Fasan of Austria and Franco Fiorio, general counsul, Republic San Marino, Washington, D.C., served as chairman and vice-chairman, respectively, for the afternoon sessions. Oscar Schachter was chairman of the evening session, and his vice-chairman was Vladimir Kopal. The Wednesday morning session was chaired by Professor Cooper, and Antonio Ambrosini of Italy served as vice-chairman. Professor Cooper also chaired the Wednesday afternoon session, and Alex Meyer was vice-chairman. ♦♦

Letting Space Test the Spacecraft



Possible applications of expandable structures in space are depicted in this Aeronutronic Div. of Ford Motor Co. illustration. The Mercury-capsule-like command center in the front space vehicle could detach from the main structure and return to earth. The vehicle at the rear prepares to rendezvous, the one at the right to enter orbit. Aeronutronic advocates space laboratories for testing spacecraft designs and materials, and is working under Air Force (ASD) contract on semirigid and nonrigid manned space structures.

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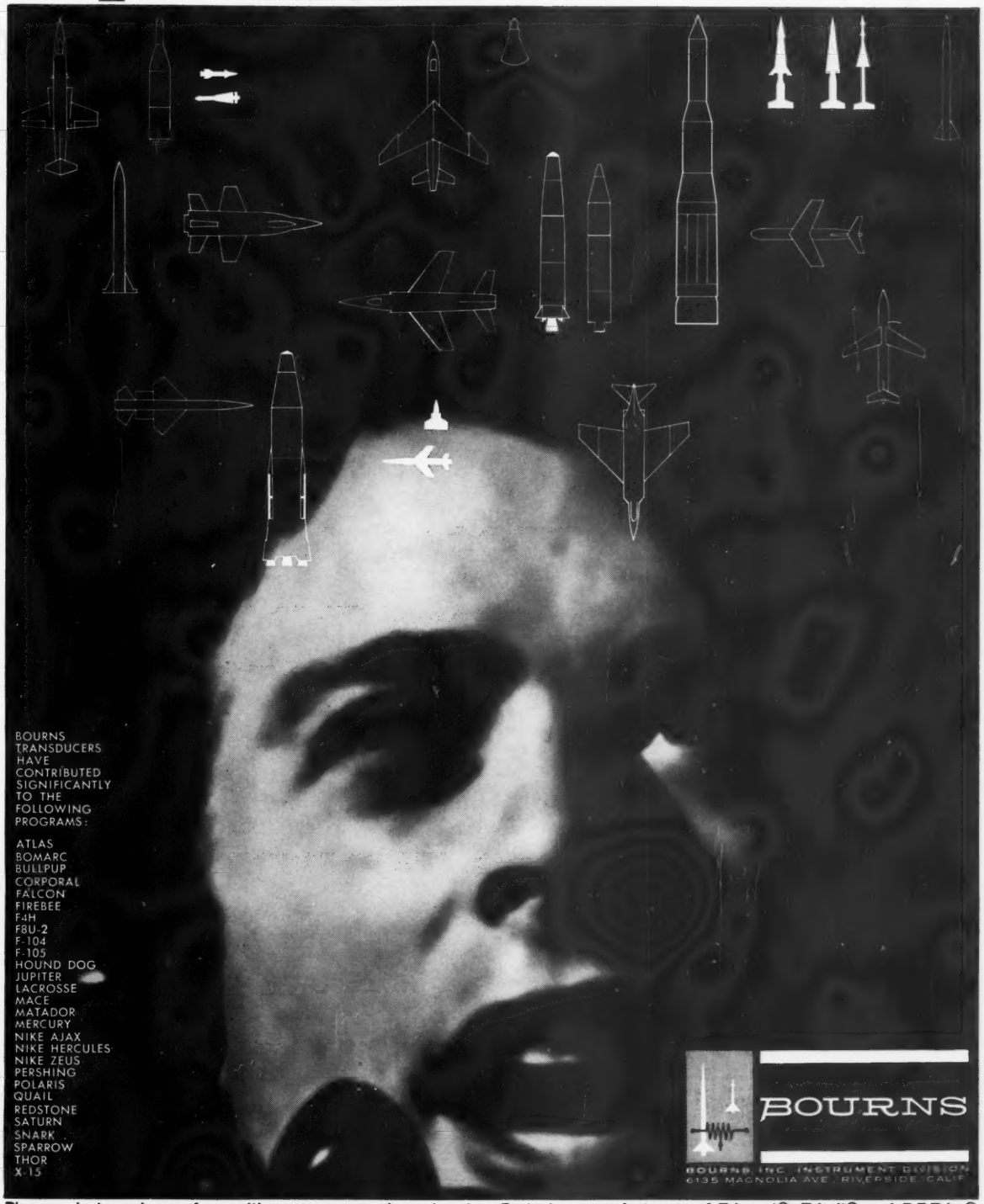

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Missiles and Space Vehicles

(CONTINUED FROM PAGE 44)

satellite families were launched, for example, two Transits, Tiros III, five new Explorers, and seven new Discoverers (totaling 34 Discoverers in all). An unmanned Mercury capsule was orbited and recovered successfully after one circuit of the earth. Manrating tests were completed on Atlas, qualifying it for Mercury flights scheduled for late this year or early next. A great Saturn flight with dummy upper stages was made October 27.

During 1961, we made 16 successful launches out of 24 tries (to September 1), thus improving our reliability quotient to a new high of 0.667. The international box score (U.S. vs. USSR) for successful space launchings now stands at 50 to 16 in our favor, this threefold advantage being an indication of our proportionately larger number of space projects and project teams. The Thor rocket made its 100th successful launching out of 129 tries. The corresponding ratio for Atlas was 65/98 and that of Titan was 31/43.

All these noteworthy accomplishments in space, however, provided no hint of the revolutionary changes which were taking place in conference and design rooms. A thorough study was underway of previous directives and space objectives, including such questions as "Is there a space race?" "Is there a space gap?" And "Are space "firsts" really important in the present world situation?"

New Horizons Seen

The significance of space accomplishments was becoming recognized as an index of a combination of effects, such as the level of technological advancement, plus active research and development management, plus an authoritative criterion for the selection of the priority of effort. But more fundamental than all these effects was the underlying national desire to look toward new horizons of human accomplishment and to demonstrate a better understanding of space, time, and other physical phenomena.

Evaluation of such factors was carried out by congressional and technical committees, specialists, and laymen, the majority of whom expressed belief that space "firsts" *are* important and that our government should lay plans for attempting to reverse the so-called space gap as soon as practical. The resulting decision, which initiated the largest single project in the history of mankind, was to concentrate a portion of our national effort for several years on preparations for manned lunar landing, to be implemented by such projects as Saturn, Apollo, and Nova.

From the original Atlas- and Titan-class boosters, there has evolved a need for both larger and smaller types of vehicles. The requirements for manned lunar-landing spacecraft has led to the Saturn and Nova class of boosters, whereas the requirements for mobile quick-reaction weapon systems has led to the Polaris and Minuteman types. In addition, the need for a low-cost vehicle for launching modest scientific payloads has led to the Scout class. The first-generation Atlas and Titan now serve the dual role of missiles as well as medium-class launch vehicles for interim space probes, through use of added upper stages. The Agena and Able-Star upper stages continued to serve for many of the space launches, with Centaur soon to become available for provision of increased payload capability.

The requirements for large space vehicles promise to introduce a new family of boosters, the Saturn and Nova class, capable of launching Apollo capsules on various missions in space. The transportation problem of elevating and accelerating large amounts of material to earth orbit and escape velocity will eventually be solved, it is believed, by some version of an "aerospace" plane, which will provide the recoverable booster for regular manned ferry service to space, as well as for long-range terrestrial transportation. For the present, however, the use of enlarged versions of current rocket systems appears to be the most practical approach. The financial incentive for the tremendous investment of public funds required for such an undertaking is the expected manifold return promised by such applications as worldwide communication systems, more accurate weather prediction, and other projects stemming from the advancement of knowledge through space research.

Throughout this work runs the theme of reliability. The table at bottom bears evidence to the greater emphasis in this area. Experience has shown the continuing need for each of the following steps to improve reliability:

1. Preliminary design for utilizing basic principles and practical values to avoid "reliability barriers" and excessive development costs. The difference between a "conceivable system" and a well-studied, state-of-the-art practical system (including realistic cost evaluation) is coming to be recognized by all persons associated with missile and space-vehicle activities.

2. Systematic detail design for the development of component and subsystem reliability and for thorough systems integration.

3. Planning and use of extensive development testing and the utilization of test results intelligently for the improvement of components, as well as subsystems and over-all systems.

Vehicle Size Growing

The manned-lunar-landing proposals show the tremendous increase in vehicle size and cost which will be required. Liftoff weight must be increased from our present level of around 300,000 lb to 10- to 30-million lb in the future. The accurate estimation of development problems and costs for so great a change seems dubious. Launch vehicles may grow from 9 to 30 or 40 stories high. Assembly and servicing operations present enormous problems for such large vehicles. The project costs, now scaled by tens of millions of dollars, will increase to tens of billions of dollars, and will consequently demand most careful consideration for design fundamentals and cost effectiveness. The miscalculation of project costs could be disastrous. The "optimum system" can no longer be defined solely on the basis of minimum vehicle weight, as it has been since the beginning of missile technology, but must rather be based on minimum over-all cost, including realistic estimates of system reliability and the effects of accelerated schedules.

To implement the manned-lunar-landing project, several important decisions must be made regarding booster-vehicle size and modes of operation. The first decision to be made will be one-shot versus two-shot; that is, direct flight versus docking, Nova versus Saturn. The one-shot approach requires that a single earth launching with Nova be capable of transferring

Box Score of U.S. Spacecraft Launches

Year	1957	1958	1959	1960	1961**
R* (for the year)	0	0.29	0.58	0.55	0.67
R (accumulative)	0	0.28	0.43	0.48	0.53

* Ratio of payloads orbited to total attempts.
** To Sept. 1, 1961.

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sufficient weight to the moon for the landing and return to earth. The two-shot approach, which will involve the docking of two space modules in orbit, or by rendezvous on the lunar surface, serves to divide the one-shot booster liftoff weight by a factor of 2 or more.

It is an accepted idea that interplanetary manned expeditions will require orbital docking of several space modules, even if the launch vehicles are of the Nova size. Hence, the early development of Saturn docking operations for the lunar mission appears to be a logical step.

The second decision will be on liquid versus solid propellants for Nova and Saturn vehicles. Both solids and liquids offer attractions, and problems. Liquid and solid Nova, for example, would weigh 8- to 30-million lb respectively, while corresponding weights for Saturn would be 4- to 10-million lb, respectively. High-energy chemical upper stages appear certain for either class of boosters, but the sizing of the upper stages is dependent on the modes of operation and choice of propellant for the boost phase. Eventually, nuclear or electric propulsion in upper stages will enter the picture; but at present, state-of-the-art materials and propellants are being considered, with no breakthroughs except, of course, the giant stride to stages and vehicles of large size.

The third decision, and perhaps most important of all, due to its effect upon the other two, pertains to the earth re-entry payload—whether it should be a one-man modified Mercury capsule weighing seven to 10,000 lb or a three-man Apollo capsule weighing 15,000 lb. The liftoff weight of the boost vehicle is almost directly proportional to the earth re-entry weight. The choice of the one-man capsule, therefore, would greatly reduce the booster weight, size, and development cost. A fully automatic one-man lunar-landing spacecraft can be developed in which the human occupant just goes along for the ride, so to speak, and is not required to accomplish any difficult tasks at lunar turnaround and checkout. Additional tasks can then be assigned to the astronaut which simplify the automatic system, such as manual control of the spacecraft during the lunar landing, as opposed to automatic control monitored from earth through a television link. In this manner the presence of a one-man crew can be expected to improve the reliability of a fully automatic device, without overtaxing the capability of the astronaut.

By contrast, the larger, three-man Apollo capsule, equipped with more scientific gear, will rely more heavily upon its crew for scientific observations and other functions, such as lunar turnaround and checkout operations. Obviously the larger, better-equipped payload is preferable, but it has the disadvantage of approximately doubling the launch-vehicle size, which would influence reliability, development time, cost, etc.

The one-man mission could be carried out with Saturn rather than Nova. However, the sheer loneliness of the astronaut on such a trip recommends the three-man capsule. The one-man lunar expedition is now thought too meager for a nationally sponsored project, and plans are accordingly being based on the three-man Apollo capsule. These plans will provide us much thought and work in the coming year. ♦♦

Astrodynamics

(CONTINUED FROM PAGE 37)

volumes by Paul D. Arthur, John Nicolides, and others that will tend to round out and supplement the other texts in the field discussed in last year's survey article.

One can delineate some eight subdivisions within the broad field of astrodynamics: (1) Geometry and coordinate systems, (2) astrodynamic constants (including heliocentric, geocentric, lunar, planetary, and atmospheric constants), (3) orbit determination (both preliminary and definitive), (4) perturbations (including the n-body problem and nongravitational and relativistic effects), (5) orbit prediction (including both special and general perturbations), (6) applications of astrodynamic theory (including orbit selection and modification, low-thrust orbits and geocentric orbits), (7) observation theory and, finally, (8) attitude dynamics.

Each of these subdivisions will be briefly introduced here and one or two of the 1961 advances in each area will be highlighted. As in the case of the 1960 state-of-the-art article, the published research papers are so numerous that it is impossible to properly reference all of them. A special ARS Preprint (No. 2215), to be issued early next year, will include specific references and a more thorough analysis of them.

In the subdivision of geometry and coordinate systems, advances have been made in a number of graphical techniques, as well as in the development of procedures for coordinate transformations. The problems in this area include the proper choice of coordinates for specific systems, such as the choice of selenocentric or selenodetic lunar coordinates and the proper reference equinox for interplanetary transfer orbits. Work is presently afoot, albeit at a modest level of support, at various universities and scientific research laboratories.

Astrodynamic Constants Vital

Astrodynamic constants are now generally recognized as constituting a vital research area; 1961 has witnessed their continuing improvement. The tesseral harmonics (longitudinal variations) in the earth's potential field are sharing the attention received by the odd zonal harmonics last year; Kaula, Kozai, Izsak, and others are pioneering in this area. DeVaucouleurs has done an excellent survey of planetary and heliocentric constant determinations, adopting a value for each constant. A standard set has been proposed by Makemson, Baker, and Westrom that will hopefully set the precedent for further coordination of the entire field of astrodynamic constants.

Such was also the goal of a constants meeting held at Marshall Space Flight Center, sponsored by NASA, and of the work of O. W. Williams at the AF Geophysical Research Directorate, Hanscom Field, Mass. Determination of the solar parallax, the most inspiring of the active heliocentric constant research, has been advanced by electronic measurement of the distance to Venus by Jet Propulsion Laboratory and the Russians. The results of various determinations fail to agree within the bounds of their estimated errors, and the subject is by no means closed. Relatively little has been done in the area of lunar and planetary constants. Atmospheric constants, particularly the varying solar-produced density profiles of the earth and model planetary atmospheres have been actively studied. In connection with planetary atmospheres, an argument has arisen between Sinton and Kiess, Karrer, and Kiess on the abundance of nitrogen oxides in the Martian atmosphere. Although the argument has not been entirely resolved, it does appear that the more classical description of the Martian atmosphere remains in force.

The determination of preliminary orbits through Doppler-range-rate electronic measurements has been studied by a small number of scientists. The

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work by Armen Deutsch and the application of spectrographic binary techniques is particularly outstanding, and is being extended to elliptical and perturbed orbits by Koskela.

The definitive orbit problem finds a number of investigators rediscovering the differential correction. Others such as Van Sant, Herrick, and Kochi are making very significant contributions to the improvement of definitive orbit determination procedures. The universal set of variables developed by Herrick appears to be particularly promising both for definitive orbit determination and for orbit prediction. Joseph Siry and C. V. L. Smith of NASA and Wahl and Westrom of the National Space Surveillance System are both grappling with the problem of replacing subjective expert intuition by objective orbit-determination computer programs.

Within the framework of perturbation studies, Ellis and Diana together with Rabe, Hori, Moiseyev, and others have contributed significantly to the subject of the stability of the Lagrangian libration points. The question of this stability is far from solved, however, and the utility of these stable points for space missions still remains to be demonstrated. Of particular interest here are the reported observations of dust clouds at the Trojan points of the earth-moon system.

Among the areas of nongravitational and relativistic forces, the most popular subject has been that of electromagnetic effects. Bordeau, Donley, Serbu, and Whipple have published experimental data, while Chopra, Singer, Walker, Lo, and Cappellari and many others have made theoretical studies of these electromagnetic effects. Here certainly is a fruitful and exciting new field within astrodynamics in which many problems are yet to be attacked. A close runner-up in interest to the electromagnetic influences has been the radiation pressure studies, particularly those carried out by Levin, Bryant, Zadunaisky, et al. The Echo satellite proved to be an excellent test bed for such theories.

Although attracting much less interest than general perturbations in the area of orbit prediction, the subject of special perturbations—the numerical integration of individual satellite orbits—has been investigated. A number of techniques and routines have been devised by Michielsen and Kropp and Pines. O. K. Smith has considered the convergence of Newton's method for the solution of Kepler's equation, while Dunn and Newton have proposed the use of Green's function and a new variable, respectively, for use in special perturbations. Perhaps the research having the most promise in this area is that by Sperling, who is refining the varicentric method at the Marshall Space Flight Center.

The other procedure for orbit prediction is that of general perturbations—the analytical solution of orbits without a numerical integration specialized to any given orbit. This area of general perturbations still commands the greatest attention from theoretical astrodynamicists. Paraphrasing comments by R. H. Merson: The early treatments by King-Hele, Blitzer, Roberson, and others were adequate but had inherent singularities of the order of J_2e. Musen's Vanguard Satellite theory of 1959 was an improvement but was not suitable for $0.05 < e < 0.6$. Brouwer's treatment as well as Kozai's had critical inclination singularities (where $\sin^2 i = 4/5$), so that they could not well be applied to some early Russian satellites. Thus, in 1961, much research has been accomplished in the improvement of these theories and in the alleviation of the critical inclination difficulties. At the present time, it looks as if Herrick's rather unorthodox approach of using physical variables (especially his universal variables) may be advantageous and might offer the solution to the critical inclination problem, as well as problems arising when the eccentricity is nearly zero or unity. Blitzer has studied the coupling among various gravitational harmonics and has proposed a preliminary theory that was debated by Hori. In a slightly different approach, Musen has proposed the application of Strömgren's method to satellite orbits.

Orbit Treatment Advanced

Orbit selection and modification has also attracted the attention of a large segment of the astrodynamics community. Calculus of variations and other tools of optimization theory have been effectively employed in orbit selection and modification by Leitmann, Carstens and Edelbaum, Miele, Vargo, Faulkner, and many others. An interesting theory for interplanetary orbit correction has been developed further by Breakwell. A corrective thrust is determined only after an "information settling time" that is dependent upon the noise level of the position and velocity measurements, hence allowing a smoothing time for the best steady-state prediction.

Optimum low-thrust programming has also been under study, for example, by George Leitmann. The pertinent literature in the field has been surveyed by Gene Levin.

Applications to geocentric satellites, such as the error analyses of Duke, Goldberg, Pfeffer, Braham, and Skidmore, have been published in 1961. Gedeon and Pierce have completed a rather extensive study of interplanetary orbital transfers. There were surprisingly few research papers on the applications of lunar trajectories. It is expected that the Apollo program will stimulate a new rash of studies in this area, in particular the considerations of lunar "abort" trajectories a unified onboard navigational system (that is, useful on both the outbound leg to the moon and the inbound leg to the earth) needs more careful study. The question of whether the lunar navigational system should be done principally by the man onboard the vehicle or by a terrestrial tracking net remains unanswered, but is under study by Faunk and Mayer of the NASA Space Task Group.

Finally, applications to interplanetary orbits are receiving significant attention, particularly by Ruppe and Koelle at Marshall Space Flight Center. Already mentioned here has been Breakwell's work which together with studies by Ross, Lee, and Florence will better define the best interplanetary trajectories and the proper correction points. Projecting rather far in the future, we note that Cornog has reported on some of his research on interstellar navigation. Although no more than one or two such papers appear each year, this subject will undoubtedly deserve more attention as time goes on.

Research papers involving the application of astrodynamics to observation theory have been surprisingly numerous. These works run the gamut from Kissel's general study of real-time tracking to Gebel's investigation of a super-fast electrophotographic device for making daytime satellite observations. More conventional studies have been mounted in the use and improvement of instruments for obtaining position. Yatzunsky and Gurko have supplemented some of the prior work of Koskela in the investigation of the brightness of artificial satellites.

The subject of onboard observations has stimulated a number of papers concerning the possibilities opened up by astronomical observatories in space. In particular, F. G. Smith, Triplett and Deutsch have discussed the advantages to be gained by going outside the atmosphere. Deutsch, however, admonishes us to consider carefully before placing the Palomar telescope on orbit as he feels that most of the advantages could be gained either from earthbound observations or by observations made from high-altitude balloons.

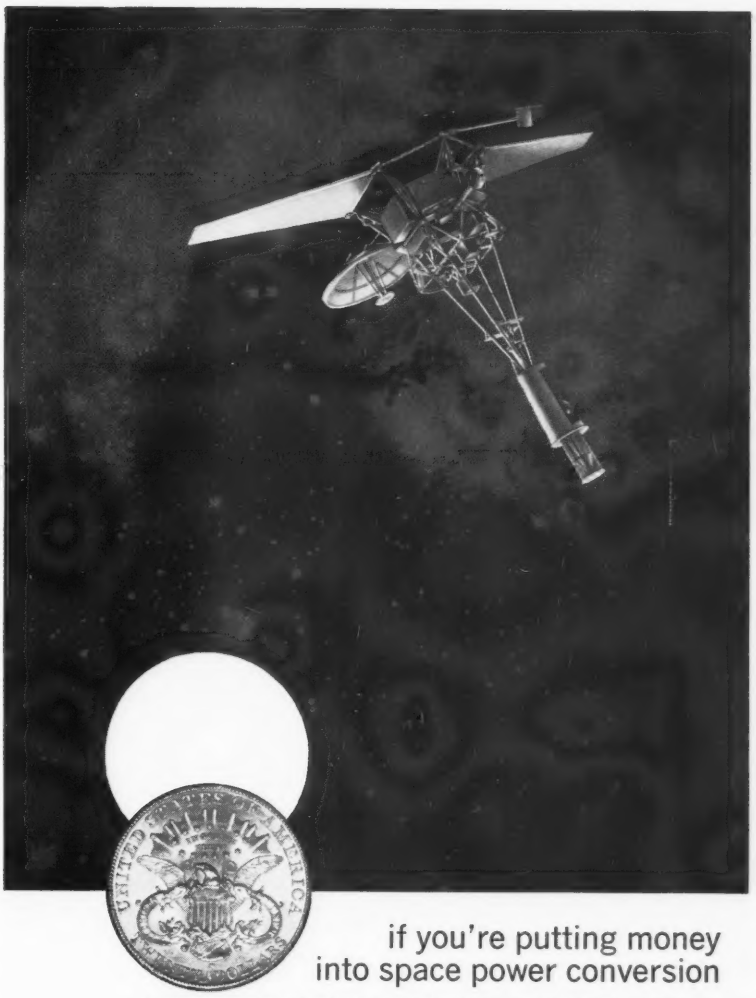
Active attitude control lies more properly within the framework of navi-

gation and guidance than in astrodynamics. Nevertheless, passive attitude dynamics, for example the nutational librations of the moon, do lie within the province of astrodynamics, and considerable research has been accomplished in this area during 1961. Burt and his associates in England have investigated the use of the gravity gradient to stabilize a toroidally shaped container, partially filled with fluid on orbit. Moran reported a more general solution of the dumbbell problem originally formulated by Klemperer and Baker in 1956. While DeBra and Delp studied the rigid-body attitude stability and natural frequencies of an object moving in a circular orbit. In this area we also find contributions by Roberson in the general formulation of the stability problem and Nidey, who has investigated the secular gravitational torque acting on a satellite traversing a circular orbit. This is related to Nidey's work on the astronomical observatory project at the Kitt Peak National Observatory.

Tidal Stability Use Dubious

It must be concluded that the use of natural tidal stability is not very promising except for certain very specialized situations.

A word should be said in conclusion about the educational aspects of astrodynamics. Important as it is to increase the number of formally educated specialists in astrodynamics, it is perhaps even more vital to insure that all space scientists are exposed to astrodynamics as a portion of their basic training. Unfortunately, there are all too few undergraduate programs in astrodynamics to serve such a requirement. The activities of Yale, Berkeley, Cincinnati, and many other institutions possessing competent celestial mechanicians are primarily centered at the graduate level. The UCLA program, consisting of four undergraduate and four graduate astrodynamics courses and offered by a staff of three astrodynamists, is presently the only complete undergraduate and graduate program offered. Furthermore, the 200–300 students participating in the UCLA program each year represent nearly 99% of the total astrodynamic educational output of the country. It is to be hoped that other universities will soon come to recognize the importance of a balanced graduate curriculum executed by a faculty of formally educated and trained astrodynamists. With the appointment of Professor Samuel Herrick to its staff as visiting professor for the coming year, MIT is pioneering this very concept. ♦♦



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ARS news

SECTION NEWS

Alabama: NASA Marshall SFC director **Wernher von Braun** and **Maj. Gen. H. N. Toftoy,** U.S. Army (Ret.), were guests of honor at the Section's 10th annual honors dinner, held at the Fort Raymond Jones Armory in Huntsville in October.

Guest speaker was **Col. James P. Hamill,** U.S. Army (Ret.), who, together with Gen. Toftoy, played a prominent role in organizing the "Fort Bliss team" of scientific, military, and industrial personnel who shortly after WW II performed rocket research at Fort Bliss, Tex., and White Sands Missile Range, N. Mex.

Col. Hamill spoke informally to an audience composed of the Section's membership, officers, and approximately 200 members of the old Fort Bliss team who in 1950 left Texas and came to Huntsville to form the Ordnance Guided Missile Center. This group included Ernst Stuhlinger, director of Marshall's Research Projects Div., Hermann Oberth, formerly with the Huntsville development team and one of rocketry's earliest pioneers, and Walter Dornberger, formerly commanding general of Peenemuende.

Also on the program was a report covering activities for 1961 delivered by **Henry M. Shuey,** the Section's outgoing president. This was followed by the installation of officers for 1962, including Walter L. Berry, president, and Hermann K. Weidner, vice-president.

The evening also saw the presentation of the Martin Schilling Award (given annually for outstanding services to the Section over the year) and two Hermann Oberth awards. The Oberth Award is sponsored by GD/Astronautics.

The Martin Schilling Award, presented by Dr. Stuhlinger, went to **Konrad K. Dannenberg,** deputy director of the Marshall Saturn Systems Office. The first Oberth award was presented to Wernher von Braun by Dr. Oberth. The second Oberth award was presented to Gen. Toftoy by Maj. Gen. John Barclay, U.S. Army (Ret.).

—J. Frank Rushton

Hermann Oberth presents Alabama Section's Oberth Award to Wernher von Braun.

Allegheny: The Section held its September dinner meeting at the Ali Ghan Shrine Country Club. **A. F. Giacco** of Hercules Powder's Chemical Propulsion Div. spoke to members and guests on "The Business of Space." The theme of the talk was the role of solid motors in space exploration.

The October dinner meeting of the Section was held at the Cumberland Country Club with about 85 members and guests in attendance. The speaker for this event was **John W. Corcoran,** chief scientist, Research and Development Div., Beckman and Whitley, Inc. In his talk, titled "High-Speed Cameras," Corcoran described the optical systems used in several high-speed cameras, with emphasis on the advantages and limitations of each type. He illustrated his talk with descriptive slides and motion pictures taken with each type of camera.

—Mary D. Eirich

Columbus: At a dinner meeting in September inaugurating a new year of Section activities, guest speaker **Kenneth E. Kissell,** associated with the Office of Aeroresearch at Wright-Patterson AFB, discussed the optical tracking of satellites. Among the subjects Kissell covered were methods of optical tracking, tracking-telescope requirements, various types of field equipment, and worldwide tracking facilities.

—James J. Komar

Connecticut Valley: Some 50 members and guests of the Section kicked off the 1962 season with a dinner-dance at Les Shaw's Restaurant in New Haven in September. Newly elected officers for 1962 were installed at the dinner: D. N. Griffin of Technoproducts, president; W. R. Kolk and S. Dolinger of Hamilton Standard, vice-president and secretary, respectively; and C. F. Turner of Olin Mathieson, treasurer. A pleasant cocktail hour sponsored by Olin Mathieson preceded the dinner.

Kurt Stehling, second from right, spoke before the Connecticut Valley Section on space futures. From left, C. F. Turner, D. N. Griffin, and M. Schweiger—vice-president, president, and meetings chairman for the Section.

The featured speaker of the evening was raconteur **Kurt Stehling,** staff scientist in NASA's Office of Program Planning. His talk, titled "Prospects of the Space Age," covered economic, technical, and political problems involved in carrying out the national space program, and dwelled at some length on the race to place a man on the moon.

—Sheldon Dolinger

Dayton: At the Section's big "annual" meeting in September, the following officers for the new year were installed: Ralph Hodge, president; Gene Babb, vice-president; Gus Schwarz, secretary; and George Gardner, treasurer. Some 75 members and their ladies and guests were in attendance at this dinner meeting, which was preceded by a social hour.

Guest speaker of the evening was **H. C. "Rick" Cotton,** program manager for Ryan Aeronautical, who spoke on its flex-wing program. The program was excellently described, with

both movies and slides indicating the wide potential of this device, which was conceived by Frances M. Rogallo, a NASA scientist, some 15 years ago.

—K. C. McClellan

Holloman: In September, the Section elected the following new officers during a dinner meeting at the Officers' Club, Holloman AFB: Col. Blake W. Lambert, president; Lt. Col. Ray O. Roberts, vice-president; Lt. A. Lee Zuker, secretary; and Lt. Col. Michael J. Barbieri, treasurer.

Outgoing president Harald Von Beckh introduced the honor guests at the head table, among whom were **Col. R. S. Garman,** AFMDC commander, and **Col. E. C. Tates,** Holloman AFB commander.

Guest speaker for the evening was **L. F. Goode Jr.,** manager for the Nike-Zeus project at White Sands Missile Range, who discussed ballistic-missile defense and, in particular, the Nike-Zeus program.

—Robert C. Whipple

Indiana: In September, guest speaker **Henry M. Shuey,** head of Rohm and Haas' ballistics section, discussed solid-propellant technology. Over 100 people attended the meeting to hear Dr. Shuey, including M. J. Zucrow, Atkins Professor of Mechanical Engineering at Purdue Univ.

A joint meeting of the Section and the Indianapolis Section of the IAS was held in late October. Approximately 100 members and guests of the two societies met for a social period and dinner and then took a tour of the Naval Avionics Facility, Indianapolis. **Capt. Barton E. Day,** commanding officer of NAFI, reviewed its history, organization, mission, and operation as an introduction.

This program was arranged by Wm. G. Emmick of GM's Allison Div., who had fortunately been named program chairman by both the ARS and IAS sections for October. The next meeting, sponsored by Linde, will feature a discussion of flame plating.

—Howard E. Bethel
and John P. Schmitt

Northern California: The first meeting of the fall season was attended by a host of new faces in addition to the "regulars" who have so well supported our activities. Section President Howard Kindsvater presented **Daniel B. DeBra** of Stanford Univ. a plaque and special commendation for outstanding services rendered the ARS during the Guidance, Control, and Navigation Conference held at Stanford in August.

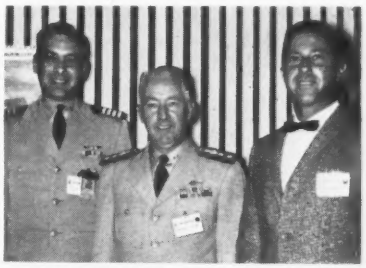
Guest speaker of the evening was **Samuel Silver,** director of the newly established Space Science Laboratories at the Univ. of California (Berkeley). Dr. Silver discussed the new arena of science which has opened with the space age.

The October meeting of the Section was held jointly with the local IAS Section at Stanford Univ. **Ivan A. Getting,** president of Aerospace Corp., addressed the meeting on the mission of his organization. Dr. Getting introduced his subject by comparing research methods which existed in the U.S. before and after WW II.

Dr. Getting compared the effectiveness of large arsenals and nongovernmental laboratories, saying that arsenals develop reputations for particular skills which were difficult to evaluate because of secrecy and lack of competition. By contrast, nongovernmental laboratories, he said, do research on a competitive basis.

—Robert O. Webster

Pacific Missile Range: September was the first meeting following publication of the list of ARS Senior Members and also the first since **Rear Adm. John E. Clark,** USN, assumed command of the Pacific Missile Range. Present at the meeting were all three ARS Senior Members attached to this activity. Besides Adm. Clark there were Capt. Carl E. Pruett, USN–MC, bio-science officer, and Stanley R. Radom, deputy director of range support. In honor of the occasion, badges indicating their senior membership were prepared, and were presented by John E. Masterson, PMR Section president. Adm. Clark spoke on the transition of research and development projects to operational programs. The occasion was a luncheon attended by 141 members and guests. The Section currently has a membership of 143 and is embarking on an active autumn program.



Capt. Carl E. Pruett, USN-MC PMR bio-science officer, Rear Adm. John E. Clark, USN, PMR commander, and Stanley R. Radom, PMR deputy director for range support sport "ARS Senior Member" badges prepared for them by fellow members of the PMR Section.

—Arthur Menken

Palm Beach: In a September meeting, the Section saw five NASA films,

1962 ARS Meeting Schedule

Date	Meeting	Location	Abstract Deadline
1962			
Jan. 24–26	Solid Propellant Rocket Conference	Waco, Tex.	Past
March 14–16	Electric Propulsion Conference	Berkeley, Calif.	Past
April 3–5	Launch Vehicles Structures and Materials Conference	Phoenix, Ariz.	Past
May 21–23	National Telemetering Conference	Washington, D.C.	Past
July 17–19	Lunar Missions Meeting	Cleveland, Ohio	March 1
Aug. 15–17	Nuclear Propulsion Conference	Monterey, Calif.	April 15
Sept. 25–28	Power Systems Conference	Santa Monica, Calif.	May 21
Mid-October	XIIIth International Astronautical Congress	Sofia, Bulgaria	
Nov. 12–18	17th Annual Meeting and Astronautical Exposition	Los Angeles, Calif.	July 30
Dec. 26–31	Space Physics—AAAS	Philadelphia, Pa.	Sept. 10

On the calendar

1961	
Dec. 3–7	AIChE Annual Meeting, Hotel Commodore, New York, N.Y.
Dec. 5–6	Conference on Status of Meteorological Rocketry at Texas Western College, El Paso, Tex. Sponsored by Army Signal Support Agency and Schellenger Research Laboratory, Texas Western College.
Dec. 26–31	Annual National Meeting of the American Assn. for the Advancement of Science, Denver, Colo.
1962	
Jan. 9–11	National Symposium on Reliability and Quality Control sponsored by IRE, AIEE, et. al., Statler-Hilton Hotel, Washington, D.C.
Jan. 24–26	ASME Thermophysical Properties Symposium, Princeton Univ., Princeton, N.J.
Jan. 24–26	**ARS Solid Propellant Rocket Conference, Baylor Univ., Waco, Tex.**
Feb. 4–7	AIChE National Meeting, Statler-Hilton, Los Angeles, Calif.
Feb. 7–9	IRE National Winter Convention on Military Electronics, Ambassador Hotel, Los Angeles, Calif.
Feb. 19	IAS Tracking and Surveillance of Aerospace Vehicles Meeting, San Francisco, Calif.
Feb. 27–March 1	Symposium on the Application of Switching Theory to Space Technology at Lockheed Missiles & Space Co., Sunnyvale, Calif. Sponsored by AF Systems Command, AFOSR, Office of Aerospace Research, and Lockheed M&SC.
March 14–16	**ARS Electric Propulsion Conference, Hotel Claremont, Berkeley, Calif.**
March 28–29	Symposium on Engineering Aspects of Magnetohydrodynamics, Univ. of Rochester, Rochester, N.Y., sponsored by AIEE, IAS, IRE, and Univ. of Rochester.
April 3–5	**ARS Launch Vehicles Structures and Materials Conference, Ramada Inn, Phoenix, Ariz.**
April 10–12	AFCRL Symposium on the Plasma Sheath—Its Effect Upon Re-entry Communication and Detection, New England Mutual Hall, Boston, Mass.
April 14–16	Second Conference on Kinetics, Equilibria, and Performance of High-Temperature Systems, sponsored by Western States Section of The Combustion Institute, at Univ. of California, Berkeley, Calif.
May 21–23	**ARS, AIEE, IAS, ISA, IRE National Telemetering Conference, Sheraton-Park Hotel, Washington, D.C.**
June 13–15	Annual Heat Transfer and Fluid Mechanics Institute, Univ. of Washington, Seattle, Wash.
July 17–19	**ARS Lunar Missions Meeting, Pick-Carter and Statler-Hilton Hotels, Cleveland, Ohio.**
Aug. 14–16	International Conference on Precision Electromagnetic Measurements, National Bureau of Standards Boulder Laboratories, Boulder, Colo.
Aug. 15–17	**ARS, ANS, IAS Nuclear Propulsion Conference, U.S. Naval Postgraduate School, Monterey, Calif.**
Aug. 27–Sept. 1	Second International Congress on Information Process of International Federation of Information Processing, Munich, Germany.
Sept. 25–28	**ARS Power Systems Conference, Miramar Hotel, Santa Monica, Calif.**
Mid-October	**XIIIth International Astronautical Congress, Sofia, Bulgaria.**
Nov. 12–18	**17th Annual Meeting and Astronautical Exposition, Pan Pacific Auditorium, Los Angeles Calif.**
Dec. 26–31	**Space Physics—AAAS, Philadelphia, Pa.**

including ones on the X-15, Pioneer space-probe series, and aerodynamic heating. Sixty members attended this meeting.

In October, 39 members gathered to hear **Dorian Shainin,** vice-president of Rath & Strong, discuss advanced concepts in reliability in aerospace technology, in particular, testing techniques optimized to obtain a maximum number of results from a minimum of tests.

A dinner meeting on December 14 will feature a panel discussion on graduate engineering education by the deans of engineering of the universities of Miami and Florida.

—Harold J. Tiedemann

Sacramento: At the July meeting, guest speaker **Howard Seifert,** immediate past president of ARS, gave a talk titled "Are Chemists Obsolete?" that dealt with nonchemical means of rocket propulsion. Dr. Seifert explained that specific impulse orders of magnitude greater than that obtainable from liquid or solid propellants will be required for many space missions. For example, a soft moon landing requires an initial velocity of approximately 9 mi. per sec for the launched vehicle. At a specific impulse of 350 sec, about 1% of the initial launched weight would be available as useful payload; at a specific impulse of 700 sec, this increases to 10%; at a specific impulse of 4000 sec, this increases to 65%; and at a specific impulse of 12,000 sec, this increases to 85%. Dr. Seifert cited other examples, related them to various schemes of nuclear and electric propulsion, and reviewed developments aimed at nonchemical propulsion, such as the Kiwi's and Snap 8. He concluded his talk with a prediction that the future of rocket propulsion rests with nonchemical systems.

At the September meeting, guest **A. K. Oppenheim,** professor of aeronautical sciences at the Univ. of California, spoke on "The Position of the Engineer in our Universities." Dr. Oppenheim quoted statistics which showed that the percentage of students studying engineering in our universities today is decreasing, and that the number in engineering in Russia is rapidly increasing. In addition, the percentage of women studying engineering in the U.S. is also decreasing. The speaker was much concerned with this situation and felt that one of the reasons for it is that engineering is losing its identity at most universities. This is due partially to the fact, he said, that the difference between engineering and science is not clear in most people's minds, including high school students and their teachers.

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The demand in the 1930's and 1940's, he noted, was to make engineering more scientific. As a result, school administrators appointed scientists to teach engineering. We are faced with a present paradox, he says, in which the expansion of technology is destroying the identity of engineering.

Prof. Oppenheim suggested that the scientist's problem is to determine the truth; the engineer's function is to solve a problem. Two conclusions: (1) Engineering today with respect to 50 years ago is based on science but involves synthesis as well as analysis. (2) In times of stress more attention should be placed on the development of the science of engineering by engineers, and not by scientists. The university, he feels, can only obtain help in this area from the profession itself and from industry.

A movie and several slides were also shown. The movie pertained to European education and showed students performing experiments in engineering laboratories. The slides pertained to the detonation research work for which Prof. Oppenheim is responsible at the Univ. of California. Shock waves in a detonation tube were shown ahead of the flame front. One of the slides showed a laminar flame creating a shock wave ahead of it.

—M. Halebsky

St. Louis: The May meeting featured a discussion of "The Medical Support of Project Mercury" by **Stanley C. White** of NASA's Space Task Group. His discussion of the development and testing of life-support systems and the doctor-engineer relationship was heard by approximately 80 members and guests, and was highlighted by a color film of Astronaut Alan B. Shepard's historic flight of the previous week. The film followed Shepard through the day from breakfast to his departure for the Grand Bahamas following the flight, and featured sequences taken from within the capsule during the flight.

The following officers were elected for the coming year: A. E. Cohen of McDonnell Aircraft, president; G. R. Little of Emerson Electric, 1st vice-president; R. S. Rippe of Olin Mathieson, 2nd vice-president; D. K. Bleikamp of McDonnell Aircraft, secretary; and J. R. Quick of Universal Match Corp., treasurer.

The fall activities of the Section were inaugurated with a meeting on October 4 featuring as speaker **Col. Robert E. Herndon,** commander of the USAF Aeronautical Chart and Information Center. Col. Herndon briefly summarized the mission of the ACIC, and followed this with a detailed description of the processes by which the information required for the charts is collected, collated, and printed. A feature of the presentation was a discussion of the lunar charts now in preparation. These highly detailed charts of the entire visible lunar disk will be invaluable in our nation's manned lunar expeditions.

—D. K. Bleikamp

Tennessee: Guest speaker at the September meeting was **C. F. O'Hara,** senior scientist in the Research Div. of Lockheed Missiles and Space Co., who is active in the fields of mathematics, solid-state physics, and ultra-high-vacuum physics. The topic of his presentation was "A Study of Slipring Materials for Spacecraft." A general survey of the problems encountered at low temperatures and pressures in the operation of sliding metal surfaces was presented. Some advantages and results of various alloy combinations and the wear and erosion rates obtained during metal-to-metal contact operation were shown and discussed. This was a very interesting talk on a problem area not often brought to the fore, but one which must be solved and is just as important as the development of any major system for successful spacecraft operation.

E. W. Schwartz, supervisor of the heat-transfer group in the Aerophysics Dept. of GD/Astronautics, was guest speaker at the October meeting. The title of his talk was "The Centaur Program." A 24-hr-orbit mission was discussed, and the thrust, coast, staging, and attitude-adjustment cycles required for successful orbit were defined. The major systems of the Centaur vehicle were defined, and some of the problems encountered in the design and development of these systems were presented. An enthusiastic question-and-answer period followed this very enlightening presentation.

At the gracious invitation of the neighboring Alabama Section, 14 members traveled to Huntsville in October to attend Alabama's annual awards-presentation dinner meeting. We were much impressed by the ceremony and by the enthusiasm of the Alabama Section members.

The ARS Univ. of Tennessee Student Chapter participated in the "Space Flight Report to the Nation" week by setting up a display of rocket motors and missile models and photographs in the Student Union Buildings at the University. **Joel Ferrell,** chief of the AEDC Rocket Test Facility, ARO, Inc., and a director of the Section, spoke before the Student Chapter on the roll which AEDC has played in the Minuteman missile program. Following his presentation, a film entitled "Man into Space" was shown.

—T. J. Gillard

Wichita: The first fall dinner meeting was held at Innes Tea Room with about 60 members and guests present. Guest speaker **Lt. Col. F. D. Bennet,** B-52 Project Officer of USAF Strategic Air Command Headquarters in Omaha, presented an unclassified discussion of the SAC airborne-alert program. Col. Bennett described SAC's primary objective as deterrence by convincing any potential aggressor that he would incur unacceptable destruction from the SAC forces remaining after any surprise attack. He illustrated his remarks with an AF color film, "Sky Watch," which described the recent history of bomber-crew training and events leading up to the current airborne-alert requirements. A typical response by SAC crews from bases all over the world to an alert was dramatized.

—C. M. Long

Arizona Forming Section

Key management and engineering personnel from many of Arizona's missile and rocket industries recently held an organizational meeting to form a Section of the American Rocket Society. C. E. Bartley, president of Rocket Power, Inc., Mesa, Ariz., and a pioneer member of the Society, spoke on the history and objectives of ARS. A color film on Rocket Power's testing facilities and propulsion products was presented by A. L. Pittinger, vice-president of Rocket Power and also an active member of the Society for many years.

Dr. Bartley stated that "in view of the fact that Arizona's technical fraternity has become such an important contributor to America's space and missile programs, it is appropriate that this key group be organized and recognized now under the banner of an Arizona ARS Section. Communication between technical people can be a powerful force in accelerating our missile and space programs, and unification under ARS can be instrumental in accomplishing this." ♦♦

C. E. Bartley

Membership Procedures

(CONTINUED FROM PAGE 61)

I would like to discuss some of the misunderstandings and problems which had arisen in connection with the new Senior Member grade. It appears that a great many persons did not fully understand the membership qualifications, which indicate that the Senior Member shall be a professional scientist or engineer with at least 10 years of experience in rocketry or astronautics who has attained distinction in his field for at least four of those years. Many of the applicants for Senior Member grade have been persons who had not been engaged in scientific or engineering work for 10 years, and many others failed to document any achievements which might qualify them for consideration for the grade. The grade was established to recognize truly superior contributions to the individual's discipline, engineering in general, the space-flight field, or the scientific or engineering professions. In too many cases, there was no documentation of any such achievements.

Furthermore, in many cases the persons referenced were not familiar with the applicants or their work, and thus were not in a position to evaluate properly the candidate's qualifications. It was originally intended that the Senior Member grade would be reserved for people whose reputations and achievements would almost certainly be familiar not only to the leading experts but to nearly everyone in the candidate's particular discipline.

Nominations Planned

Our Committee and the ARS Board felt that, by having the members of the Committee and the Board, the chairmen of Technical Committees, and Fellow Members, as well as the Sections, nominate Senior Member candidates, an eminently fair nominating procedure had been established which would give representation to organizations, disciplines, and Sections. The new procedure would fairly well assure that only genuinely qualified candidates would be nominated, and that the nominations would be on an impartial basis.

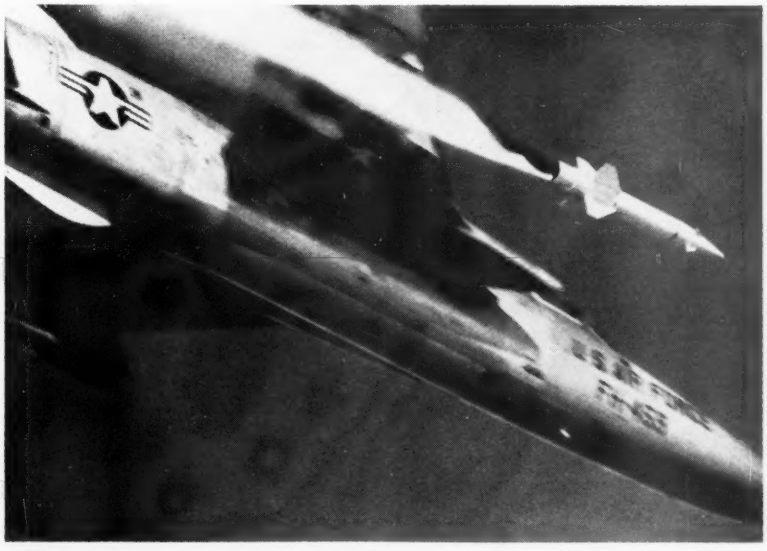
I must stress the fact that Senior Member candidates *do not* submit applications, information, or references. All information regarding nominations for Senior Member grade, which will be reviewed by the Membership Committee, is to be gathered and submitted by the nominator himself. The Committee feels that this is an important change which will go a long way toward insuring that all the necessary and applicable information, along with suitable references, will be provided, and that it will restrict the nominations to only genuinely qualified candidates.

A brief review of why the new membership-grade structure was instituted in the first place may help explain the Board's action. In 1960, the ARS Membership Committee decided that a reorganization of the Society's membership grades was in order so as to better recognize professional experience, competence, and achievements. The Committee felt that the addition of another grade, to be called Senior Member, was necessary to achieve this purpose. Membership qualifications for the Associate Member and Member grades were also tightened up, and another new grade, that of Benefactor, established. Under the chairmanship of William L. Rogers, the Membership Committee met a number of times and devoted a great deal of thought and planning to the proposed new membership grade structure.

That Committee then passed on to the 1961 Membership Committee a complete plan, which was presented by me, as the new chairman, to the ARS Board, which, after considerable discussion, returned it to the Membership Committee for redrafting. This was done; and in the spring, the Board gave final approval to the new ARS membership structure, which went into effect July 1.

Inasmuch as the new Senior Member grade required references by two other Senior Members, it was decided to appoint a committee to name a group of charter Senior Members known to be beyond question highly competent professionally, and geographically and organizationally located so that any future applicant for the grade would be virtually assured of knowing and being close to a charter Senior Member. This original list was not intended in any way to produce an elite group of members or to slight or impugn the professional capabilities of any persons not named in that group. Furthermore, the panel appointing the new Senior Members was limited by its personal knowledge of ARS members and could not, nor did it expect to, name every ARS member who was eligible for the new grade.

The Committee and the Board of Directors sincerely hope that these new measures will prove equitable, not only to present ARS members but to future candidates for membership as well. ♦♦



Bullpup Launch

A Republic F-105 fighter-bomber launches a Bullpup-A air-to-ground, radio-controlled missile. Thiokol's Reaction Motors Div. produces the Bullpup-A storable liquid-propellant motor. Martin Co. is prime contractor for Bullpup. Rounds have been ordered in large quantities recently as part of the "limited warfare" buildup.

Space Law and Sociology

(CONTINUED FROM PAGE 51)

sources and the legal incidents of space travel?

It is believed that the publication of national and international flight rules in a single language and a single document will promote the general knowledge and understanding of the air laws of other countries, encourage the adoption of more uniform laws, and eventually assist in accomplishing an international agreement on the peaceful uses of outer space.

Two other "milestones" of research effort were the publication (1) in the sociological field, by The Brookings Institution, of "Proposed Studies on the Implications of Peaceful Space Activities for Human Affairs" compiled under the direction of Donald N. Michael, with the collaboration of several experts, for the NASA Committee on Long-Range Studies and (2) in the legal field, by the American Bar Foundation, of a "Report to NASA on the Law of Outer Space" by Leon Lipson and Nicholas deB Katzenbach, in collaboration with several experts. In any event, the foregoing are types of activities which must form the basis for considered judgments.

The ARS Space Law and Sociology Committee in its meetings during the past year has endeavored to "steer a course" along the lines of practical studies. Congressional legislation affecting the aerospace business has been carefully followed. Numerous studies have been made on government patent erosion and programs of protection of private rights—matters which have become of great importance during the "space age." As a matter of fact, at the National IAS-ARS Joint Meeting in Los Angeles last June, the foregoing subjects were covered quite thoroughly. In the two lengthy sessions held at the ARS Space Flight Report to the Nation, the legal problems and the potentials of space communication were carefully examined. The patent problems were again discussed and "A Model International Convention on Inventions in Space" was presented. Soviet views on space law and the character of international cooperation in space, as well as the emerging customary law of space, were treated with precision and in a most factual manner.

Pursuant to an invitation from David R. Abell, executive secretary of Columbia Univ.'s Society of International Law, the writer submitted to the Columbia Society a program for the production of "position papers." This program actually was conceived by the writer in connection with the "Working Group" activities of the International Institute of Space Law, and it is now hoped that the ARS Space Law and Sociology Committee will participate in this work during 1962. The main purpose is to achieve "positions" on rather narrow issues and thus gain more functional discipline for our field.

For example, in the field of space communications, the following issues may be asserted on an international basis [many new issues will arise during the next few months]:

1. What provisions should be made for the determination by national and international organizations of the nature and extent of the requirements for the use of radio in space-flight activities? What is the status of current knowledge as to the extent of such requirements at present and in the foreseeable future?

2. What provisions should be made for the determination by national and international organizations of the radio frequencies available for use in space-flight activities? What is the extent of current provisions in national and international law for allocations for such uses of radio frequencies?

3. What provisions should be made for international agreement on interference involving radio frequencies used in space flight, including the following subjects:

   a. Interference to radio transmissions in space-flight activities.
   b. Interference from radio transmissions in space-flight activities to other uses of radio.
   c. Termination of transmissions from radio transmitters in space, especially those operating unattended.
   d. Establishment of priorities for transmission and reception involving space-flight activities where interference would result from simultaneous transmissions from several sources.
   e. Identification of transmissions to aid in the determination of the sources of transmissions and of interference.

4. Is the International Telecommunication Union (ITU) presently constituted so as to be capable of regulating the use of radio in space-flight activities? To this end, what are the present legal capabilities of the ITU with regard to the matters listed below, and in what respects should the International Telecommunication Convention and the Radio Regulations of the ITU be enlarged, or modified, so as to permit the resolution of these issues:

   a. In what manner should radio frequencies be allocated for use in space-flight activity, that is, on an exclusive basis, on a shared basis involving other uses, to individual nations, to world organizations and the like?
   b. What is the extent of the ITU's jurisdiction? Can frequency allocations be enforced by the ITU as to uses outside the earth's atmosphere?
   c. Are the existing agencies of ITU capable of making continuing studies of the uses of radio in space-flight activities? In what respects should the agencies of the ITU coordinate such studies with other bodies such as the IAF?

In the field of international cooperation, position papers are necessary to respond to these questions or issues:

1. What international organizations, governmental and nongovernmental, are presently concerned with the regulation of space activities?

2. To what extent may these existing organizations (such as the International Astronautical Federation) serve as agencies for the regulation of various activities in space?

3. Should new international organizations be established for the promotion and coordination of activity in outer space?

4. Should a committee be formed to draft an international agreement, modeled on the Antarctic Treaty of Dec. 1, 1959, to limit the use of outer space to peaceful purposes?

5. What arrangements should be made for the creation of international agreements covering:

   a. Cooperation in space exploration.
   b. Prohibition of the use of artificial satellites and celestial bodies for certain purposes.
   c. Cooperation in the development of space law.
   d. Provision that space problems not covered by existing law be settled by negotiation or arbitration.
   e. Establishment of methods for dissemination of basic scientific data regarding space flight.
   f. Establishment of space-data centers and research institutes.
   g. Operation of international satellites and space platforms.
   h. Prompt return to the launching country of space vehicles, equipment, and personnel which have landed or crashed on the territory of another sovereign state.
   i. Use of satellites in charting aids to ship and aircraft navigation.
   j. Inspection and control of

armaments on space flights, particularly nuclear weapons, as well as controls suggested for policing the peaceful uses of atomic energy.

k. Adoption of an "International Space Navigation Code," analogous to the "International Code of Signals on the High Seas."

The evermore confused field of jurisdiction and sovereignty might well receive clarification by specific response to these questions:

1. What theories have been advanced by recognized commentators as to the point at which air space (atmosphere) ends and outer space begins?

2. Under treaty and international custom, practice and procedure, what generally by definition and judicial precedent is considered to be the upper limit of national sovereignty?

3. What are the jurisdictional and sovereign rights of nations in the air space (atmosphere) above the terrestrial boundaries of their sovereign territories?

4. What are the rights of passage, if any, of peaceful scientific rocket vehicles through such air space both on the occasion of launching and on the occasion of re-entry?

5. What is the legal status of a rocket vehicle traveling in such air space?

6. What rights, if any, do nations have with respect to a rocket vehicle penetrating such air space, such as the right to capture or destroy a rocket vehicle penetrating therein?

7. What is the present legal status of outer space, namely the area of the universe beyond the air space (atmosphere) of the earth, giving consideration to the legal effect of the acquiescence of nations to the free use of outer space by space vehicles as the result of the International Geophysical Year and of subsequent informal and formal understandings among nations?

8. Does the legal status of extra-solar space or extra-galactic space differ from the legal status of outer space comprised in our solar system or any portion thereof?

Burgeoning Social Science

More and more books are being written and more and more speeches are being given on the fascinating subject of man's legal and social status in outer space, and it is hoped that from this great effort the social sciences will be sufficiently informed to closely follow the natural sciences. ♦♦

Canadian Aeronautical Inst., Astronautical Society Merge

The Canadian Aeronautical Institute (CAI) and the Canadian Astronautical Society (CAS), Canada's two largest professional societies in the field of astronautics, are merging into a new society—the Canadian Aeronautics and Space Institute (CASI).

Announcement of the proposed merger was made at a symposium on Interplanetary Exploration jointly sponsored by CAI, CAS, the Univ. of Toronto Institute of Aerophysics, and the David Dunlap Observatory, held October 26–27 in Toronto.

CAI, formed in 1954, has about 2100 members and for some time has had an Astronautics Section. CAS, founded in 1957, has about 200 members. A/C W. P. Gouin (RCAF) of the National Defense College is CAI president, while I. I. Glass of the Univ. of Toronto Aerophysics Inst. is chairman of its Astronautics Section. Phillip A. Lapp, chief engineer, Special Products Div., De Havilland Aircraft of Canada, is CAS chairman.

Headquarters of the new CASI will remain in Ottawa, where the present CAI offices are located. An effort to bring the Astronautical Society of Canada into the new Institute will probably also be forthcoming.

The two-day symposium attracted an attendance of about 85 people, who heard eight papers dealing with experiments in terrestrial, lunar, and planetary space. Of special interest were two papers dealing with the Canadian Topside Sounder satellite.

—I.H.

NSF Calls for Antarctic Research Proposals

The National Science Foundation has announced that final proposals for Antarctic research for the 1962–63 season should be submitted by Feb. 15, 1962, to allow the necessary time for scientific review and field planning.

Proposals will be accepted for aurora and airglow, biology and medicine, cosmic rays, geodesy and cartography, geology, geomagnetism, glaciology, gravity, ionospheric physics, meteorology, oceanography, seismology, and for such other research as may be pertinent to Antarctica.

The staff of the Office of Antarctic Programs of the NSF will be pleased to discuss ideas for proposals informally prior to their final submission or to answer questions regarding the preparation of proposals and problems of research in the Antarctic.

Proposals should be addressed to the Director, National Science Foundation, Washington 25, D. C., Attn.: Office of Antarctic Programs.

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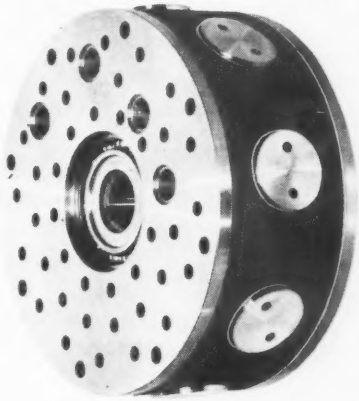

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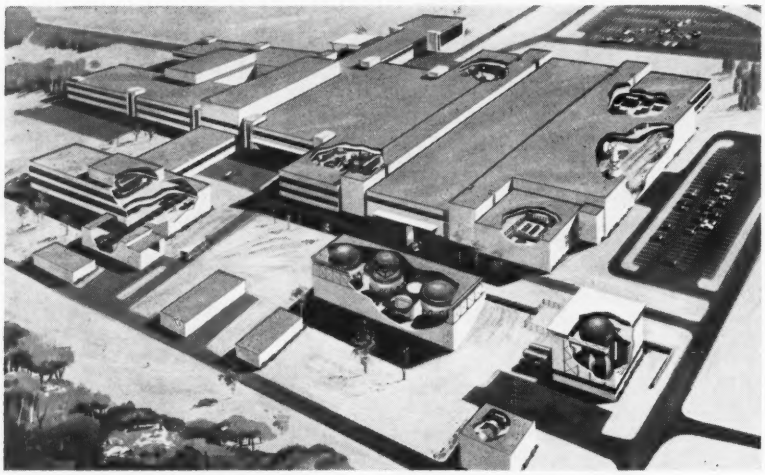


Sketch of GE Valley Forge Space Technology Center.

The sketch depicts General Electric's new Valley Forge Space Technology Center, scheduled to be completed early in 1962. At the lower right appears its Space Environment Simulation Laboratory, which reproduces vacuum (10^{-8} mm Hg), thermal (wall emissivity, 0.95), and solar environments of space with test vehicles up to 20 ft in diam. To the left of this, now nearing completion, appear three vacuum- and thermal-environment test chambers that take vehicles 21.6 ft in diam when helium is used for cooling and 30 ft in diam when helium is not used. All chambers at the Center can take test vehicles weighing up to 10,000 lb.

Physics of the Atmosphere

(CONTINUED FROM PAGE 46)

atomic oxygen atmosphere, since the required temperature would far exceed all other indications. Neither could an oxygen-hydrogen atmosphere satisfy the requirements, since the concentration of hydrogen would need to be an order of magnitude greater than that determined from the self-reversal in the profile of the solar hydrogen Lyman-alpha line. By introducing helium into the atmospheric model, with scale heights of 150 km at 900-km altitude and 300 km at 1500-km altitude, the satellite drag was accounted for. Complete mixing of helium with the atmosphere was assumed up to 105 km where the concentration was taken to be 3×10^7 per cc, followed by diffusive separation. A proposed model of the atmosphere shows atomic oxygen as the principal constituent from 200–1000 km, helium from 1000–3000 km, and atomic hydrogen above 3000 km.

Some experimental evidence has been derived to support these theoretical predictions. Hanson has analyzed rocket data of ion-probe experiments by Hale, and finds evidence for a layer of helium ions extending from 1200–3500 km. Analysis of retarding potential measurements performed with ion probes aboard Explorer VIII by Bordeau, Whipple, Donley, and Bauer indicates almost equal concentrations of He^+ and O^+ near 1600 km. Currently planned mass-spectrometer experiments should soon provide definitive answers to the problem of atmospheric composition at exospheric altitudes.

Various new measurements were made of electron, ion, and neutral-gas temperatures in the ionosphere. Jackson and Bauer deduced a neutral-gas temperature of 1640 K at 3 p.m. local time from the measured electron-density profile between 350 and 625 km over Wallops Island. Hanson and McKibben obtained an ion-density profile to 750 km, using an ion trap, and deduced a temperature of 1240 K at 10 p.m. local time for the range 350–750 km. Explorer VIII measured electron temperature directly with a modified Langmuir probe and found a maximum temperature of 1800 K in the late afternoon. A minimum temperature near 1000 K was observed between local midnight and local daybreak. These measurements may be compared with Blamont's optical Doppler temperature measurement of 1450 K at sunset, obtained by observing a sodium-vapor release.

An interesting measurement of minor ionospheric constituents was made by a Russian geophysical rocket, launched on June 15, 1960, that was equipped with an ion spectrometer of improved sensitivity. In addition to detecting the expected NO^+, O_2^+, and O^+ ions, it revealed ions of Mg^+ and Ca^+. The Mg^+ distribution maximized at about 105 km with a density of about 10^4 per cc. The distribution had a fairly sharp lower boundary immediately below 105 km and a slow tail-off with altitude to 150 km. These results support the meteor hypothesis of the origin of calcium, magnesium, and iron in the E-region.

Solar Spectroscopy. Steady progress continues to be made in solar ultraviolet spectroscopy. Hinteregger of AFCRL has obtained spectra of improved resolution, and has reduced the stray-light background with his telemetering photoelectric spectrometer for the 60–1300 Å region of the spectrum. Austin and Purcell of NRL succeeded in photographing the spectrum of the region 170–400 Å. By using an aluminum filter transmitting from 170–850 Å, stray background radiation was almost completely eliminated. The surprising feature of this new spectrum is that, of the 50 lines measured between 170 and 310 Å, only He II (304 Å) is positively identifiable. A fundamental study of emission spectra of highly ionized plasma at these wavelengths is called for to solve the mystery of these coronal and chromospheric lines.

Garrett, Purcell, and Tousey recently succeeded in photographing the spectral range 2200–4000 Å with an echelle spectrograph flown in an Aerobee-Hi rocket. The echelle is an optical staircase, ruled with 2000 steps per inch over a length of 5 in. Each step is accurately spaced with respect to its neighbors with a precision of better than 10^{-7} inch. Interference between reflections from successive steps takes place in high orders (about 200) and thereby provides a resolution of better than 0.05 Å. To record the entire spectrum on a small area of film, the echelle was crossed with a fluorite prism. The folded spectrum, shown on page 47, measured only 1-in. square, but revealed as many as 5000 Fraunhofer lines. Great interest attaches to this spectrum because it covers a wavelength region which includes lines of lead, gold, the halogens, and other elements which are not available or are unresolvable in the visible range. The new spectrum is a worthy ultraviolet counterpart to the famous Utrecht Atlas of solar emission lines,

derived from ground-level measurements at wavelengths longer than 3000 Å.

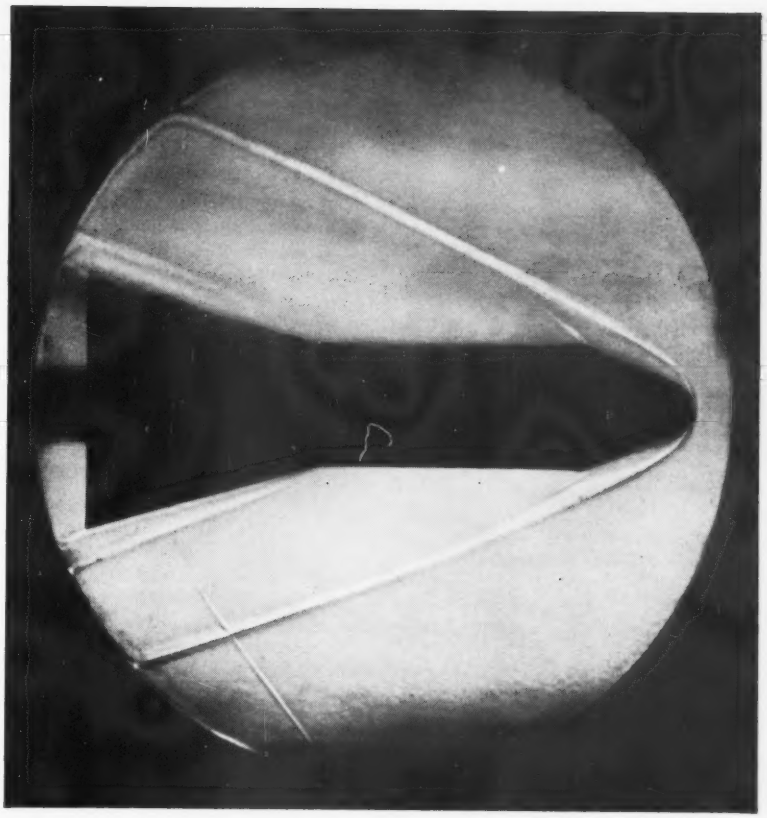
The NRL Solar Radiation I Satellite was turned off after about nine months of useful data transmission because its spin had damped out and it was providing only infrequent solar signals. During its lifetime, it measured a variety of solar events. The question of enhancement of Lyman-alpha during solar flares was clearly answered, at least for flares of Class 1 to 2 importance. Within the accuracy of measurement, no variation of Lyman-alpha could be detected. In sharp contrast, almost every evidence of solar activity was accompanied by an enhancement of its X-ray emission.

R. W. Kreplin has examined nearly a hundred X-ray events appearing in the telemetry records of SR I. In almost half of the cases, no confirmation of an optical flare was available. Presumably many of the X-ray events were associated with microflares too small to be documented in catalogs of visible flares. It seems clear that X-ray emission is an extremely sensitive gauge of solar activity. SID phenomena were observed whenever the X-ray flux exceeded 5×10^{-3} erg cm^{-2} s^{-1} in the 2–8 Å bandwidth of the X-ray ionization-chamber detector. In all events associated with flares, the enhanced X-ray emission started and terminated in close correlation with the visible onset and decay.

Solar Events Analyzed

On July 24, 1960, there occurred a sudden disappearance of a large prominence seen above the east limb, between 0900 and 1200 UT. As this event progressed, enhanced X-ray emission was observed on six successive telemetered records, the mean flux reaching 5×10^{-3} erg cm^{-2} s^{-1} at 1020 UT. There were no flares visible on the disk at this time. Correlations have been noted by Kleczeck and Krivsky between sudden enhancements of atmospherics and loop-prominence activity, or limb surges. The satellite observations reveal that it is the associated X-ray emission that produces the ionospheric effects. Among the X-ray events observed by SR I were some coincident with gradual radio fadeouts. In contrast to the explosive behavior of a typical flare event, these exhibited a slow growth of X-ray emission paralleling the ionospheric response. No visible flare activity was observed in such cases.

Rocket and satellite observations of solar flare X-ray emission have been supplemented by balloon observations. Solar X-ray bursts with quantum energies exceeding 80 kev were de-



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tected by Vette and Casal during Class 2 and Class 1 flares on Oct. 12, 1960. The observed fluxes were a few times 10^{-6} erg cm^{-2} s^{-1}, extrapolated to the top of the atmosphere within the energy interval 20–80 kev. The rise times of the events were shorter than 1 sec and the decay times did not exceed 2 or 3 min. A remarkably close correlation has been noted by Kundu between the shape of the X-ray burst and a coincident burst observed at 2800 Mc/S during the Class 2 flare.

Interplanetary Gas and Dust. Measurements with ion traps aboard deep-space probes have begun to yield direct information on the composition of interplanetary space and the question of solar winds. Gringauz recently summarized the results of measurements made aboard Luniks II and III and the Russian Venus probe. Data obtained at 126,000 km aboard Lunik III gave no evidence of a thermal, stationary interplanetary gas with a concentration in excess of a few particles per cc. At energies greater than 20 ev, the ion traps indicated currents corresponding to streams of about 4×10^8 cm^{-2} s^{-1}. The particle velocities were not determined in these measurements. Repeated observations were made aboard Lunik II of corpuscular streams at distances of several hundred thousand kilometers in good correlation with increases of the magnetic K index at the earth. The most intense stream was recorded aboard the Venus probe in February 1961. At a distance of nearly 2-million km, a 20-min radio contact recorded a positive flux of 10^9 cm^{-2} s^{-1}. By relating this event to the passage of an active solar plage across the central meridian, the velocity of the stream was estimated at 400 km per sec. The proton concentration was therefore about 25 cm^{-3}. Such concentrations are, of course, far smaller than predicted by proponents of strong solar winds.

Explorer X Results

Explorer X, launched on March 25, 1961, carried a plasma probe designed by Bridge and Rossi. Its orbit was highly eccentric with an apogee of 145,000 mi. and perigee of 100 mi. Preliminary reports of results from this experiment are not unlike those derived from the Russian experiments. In periods of extreme quiet, no probe current was detected. At times of magnetic activity, plasma streams were encountered with concentrations of the order of 10 per cc.

Important indirect evidence concerning the nature of the magnetic fields and particle fluxes in space was obtained from studies of flare events, in particular those of November 1960. T. Gold has summarized the evidence as follows:

1. Ten to 100-mev solar proton fluxes are closely associated with flares that are accompanied by Type-IV radio-noise bursts (identified with the synchrotron process).

2. The probability is high for observing a solar-proton event if it occurs in the midst of a Forbush decrease.

3. The flux of protons may be strongly increased by the onset of a Forbush event.

Gold hypothesizes that an explosion in the form of a solar flare leads to the creation of a magnetic bubble, ballooning out from the sun. The magnetic lines of force were originally almost all anchored in solar material at a lower level which was not disturbed by the explosion. Therefore the lines of force of the entire bulge remain connected to the sun. The majority of flares produce such magnetized bulges extending outward from the sun. A magnetic storm on the earth is thus caused by the earth being engulfed in the bulge. A Forbush decrease may then be produced by the partial exclusion from the interior of the bulge of cosmic rays of external origin.

With this picture, the same fields that exclude the galactic cosmic rays would guide solar protons to the earth. The occurrence of a Forbush event should be followed by an increased likelihood of obtaining solar cosmic rays from a subsequent flare. Observations of the Nov. 12, 1960 event appear to confirm the picture that when the earth was hit by solar gas and magnetic field, the field remained connected to the sun, permitting subsequently produced flare cosmic rays to flow freely to the earth along the magnetic connection.

A great many experiments have been performed with rockets, satellites, and space probes to determine the dust-particle distribution in the vicinity of the earth, but in general the results have been highly confusing. A year ago the observational data seemed to indicate a high concentration of fine dust near the earth. Recently results tend to discount this conclusion. Theoretically, it has been pointed out that there are difficulties in accounting for such a concentrated dust belt several orders of magnitude above the interplanetary level, fairly close to the earth. Explorer XIII, launched on August 25, had a very short lifetime—only two days—but within that period provided sufficient data to enable McCracken, Alexander, and Dubin to determine that the distribution function of particles with mass increases very rapidly for masses below 10^{-7} grams. This deviation from a straight-line function of log number versus log mass of particles destroys the basis for the earlier conclusions that particle density decreases rapidly with decreasing distance from the earth.

Whipple has summarized the uncertain status of this entire subject in the following three alternatives:

1. Previous rocket acoustical data grossly overestimated the occurrence of fine meteoritic particles. The postulated dust belt surrounding the earth would accordingly dwindle to a minor effect arising from the gravitational potential of the earth.

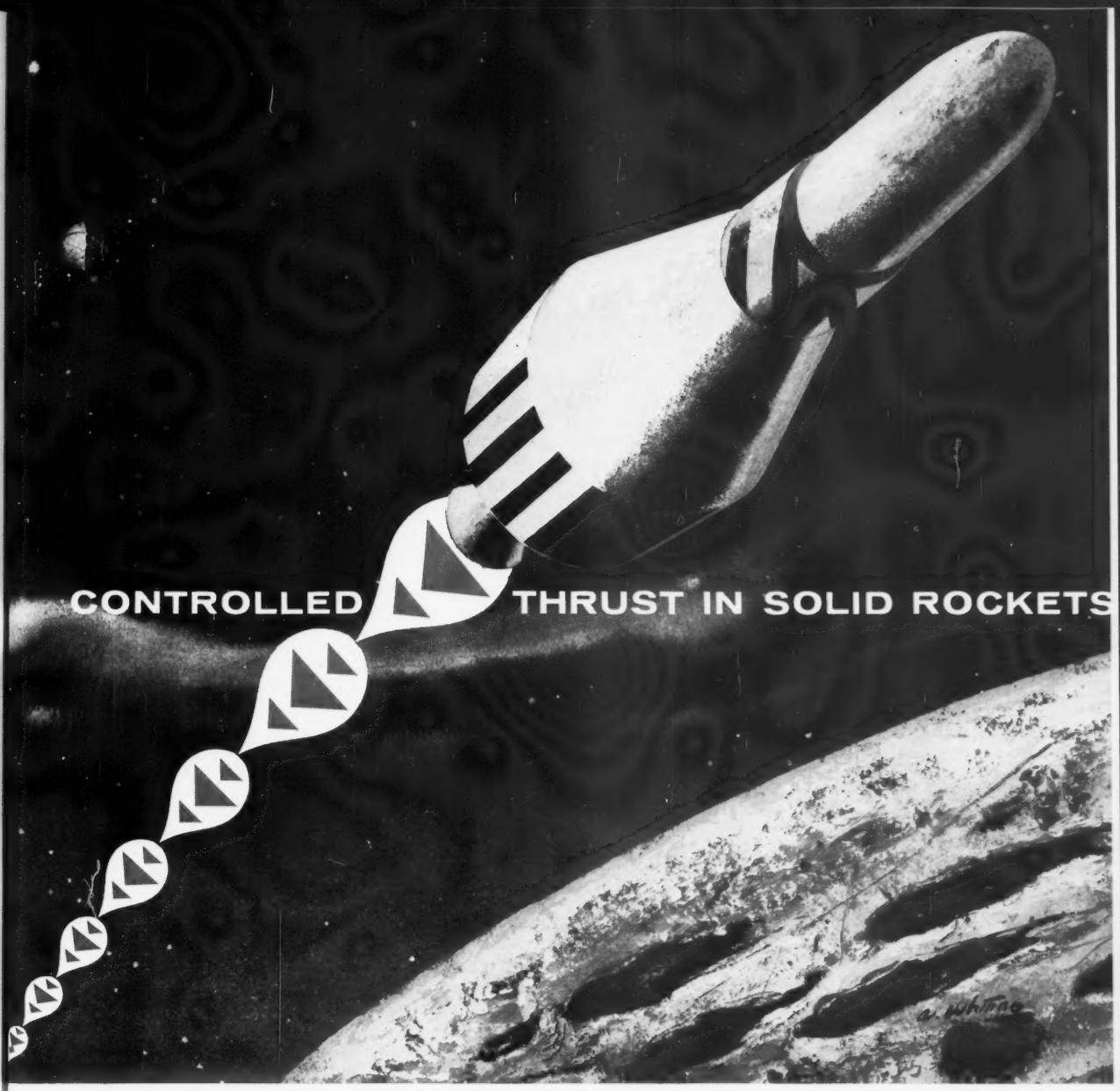
2. The distribution function of particles versus mass is very heavily weighted at the small end of the scale. This conclusion is in contradiction to the zodiacal cloud observations by a factor of 10^3 or more, if it is assumed that the small-particle distribution persists over a large volume of space near the ecliptic. A phenomenal disintegration of large particles near the earth would be required.

3. A truly large concentration of particles exists close to the earth's surface, the maximum being perhaps as much as 10^4 times the zodiacal cloud requirements. The extent of the cloud would need to be so small astronomically as not to contribute to the zodiacal light in any measureable way.

Gamma-Ray and Ultraviolet Astronomy. The purpose of Explorer XI, launched on April 27, 1961, was to map the galactic distribution of high-energy gamma rays. Primary cosmic rays of galactic origin are hard to measure, even from satellites at great altitudes, for a variety of reasons. It is difficult to separate out the fast-moving protons of the Van Allen belts. Since the primaries are charged particles, their paths through the galaxy are bent and twisted by galactic magnetic fields, so that the direction from which they seem to approach the earth is entirely unrelated to the direction of the original source.

Gamma-Ray Clues

On the other hand, gamma rays traverse the galactic fields without deflection, and their direction of arrival corresponds to the original direction of emission. Gamma rays which reach the earth's vicinity can therefore provide an indication of the direction of the source of primary cosmic radiation. Fast protons in collision with atomic nuclei produce π-mesons. An electrically neutral π-meson has a mean lifetime of less than 10^{-15} sec, following which it decays into a pair of gamma rays emitted in opposite directions. Each gamma ray, therefore, signifies a collision between a primary cosmic ray and a particle of interstellar hydrogen or perhaps dust, and the direction from which the gamma



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ray arrives points to the source of the event. The intensity of gamma radiation would be proportional to the product of the primary cosmic-ray flux and the density of matter integrated in the direction of observation. The mass equivalent of the neutral π-meson is about 135-million ev. Adding this to the high kinetic energy of the meson before decay indicates that the two quanta of gamma radiation must each have of the order of a 100-million ev of energy.

The gamma-ray telescope, designed by Kraushaar and Clark of MIT for Explorer XI, is a stack of scintillating crystals coupled to an array of eight photomultipliers. The scintillators and detectors are so arranged that it is possible to distinguish the cosmic gamma rays from all types of particle events. It was originally planned that Explorer XI's data would be stored on tape and telemetered to earth on command within a 2-min period during each orbital revolution. Alternatively, data could be transmitted on command in real time. Unfortunately, the tape recorder failed shortly after launching; and although the detector is performing satisfactorily, the data acquired is limited to that recorded in real time. The number of gamma rays detected per unit time is extremely small, and it will take months of observation before it is possible to identify any preferred directions of arrival.

In the field of rocket astronomy, an important achievement was the first measurement of stellar ultraviolet spectra with a grating spectrometer by Milligan and Stecher of NASA. The spectrograph, designed by the Univ. of Rochester, was flown in an unstabilized Aerobee rocket and scanned the sky at random. Spectra were obtained with 50-Å resolution of at least six stars in the range 1700–3000 Å. Preliminary analysis indicated a large ultraviolet deficiency for B-type stars, beginning near 2200 Å, compared to predictions of present stellar models.

VLF Propagation. The Naval Research Laboratory Lofti-1 experiment was launched with the Transit III B navigational satellite from Cape Canaveral on Feb. 21, 1961. VLF radio signals from Navy Station NBA in the Panama Canal Zone were picked up by a receiver in the satellite and retransmitted over VHF telemetry channels to NRL and NASA ground observation stations. In observations made at NRL's Stump Neck, Md., station, very strong signals from Navy Station NBA were recorded when the satellite was 1000 mi. to the north of the NBA station and at an altitude of 325 mi. In other observations made at the NRL San Diego, Calif., station, signals were received when the Lofti satellite was 3700 mi. to the west of the Canal Zone transmitter.

For many years it has been believed that VLF radio energy did not penetrate the ionosphere to any significant extent, but instead was largely propagated along the space between the ionosphere and the surface of the earth. Lofti-1 positively demonstrated for the first time that the VLF radio energy does penetrate the ionosphere to a considerable extent at a low angle of incidence. This discovery disproves the previously held concept that the ionosphere is an opaque reflective surface to VLF radio emissions.

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Power Systems

(CONTINUED FROM PAGE 47)

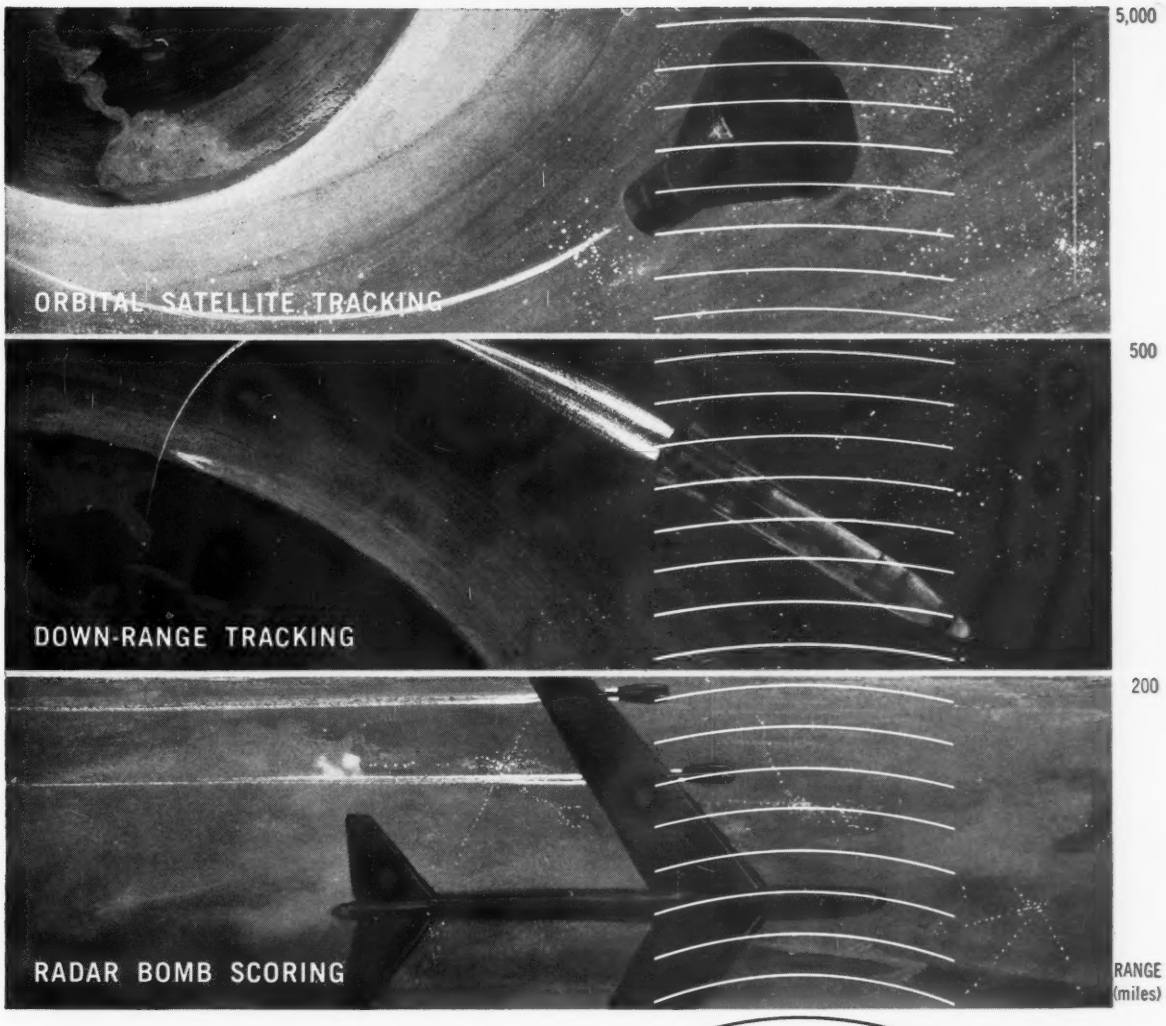
efficiencies of devices constructed so far (with single-element arms) is about 10%, operating between 950 and 300 K (cascaded units have achieved around 12%), but the over-all conversion efficiency of hydrocarbon-fueled generators is about $2^1/_2$%, and of radioisotope units around 5%.[2] Specific powers of 2 watts/lb have been obtained, and 12 watts/lb appear feasible.

Thermionic Converters. There are at least three current approaches to cesium-filled thermionic converters, as follows: (a) The use of a carbide cathode at temperatures near 2000 C (the cathode is then uncoated, so that its work function is that of the carbide), (b) the use of a refractory metal, such as tantalum or molybdenum, but at a somewhat lower temperature and at cesium vapor pressures such that the cathode receives a cesium coating, and (c) the use of a low-work-function, low-temperature (around 1000 C) "L" cathode (a porous tungsten plug impregnated with barium oxide) with a third element for cesium-ionization purposes.

In the first case, sufficient cesium ionization may be produced by contact of cesium atoms with the bare cathode. In the second, the cathode-anode spacing will be closer and the cesium pressure higher. The cathode temperature and cesium pressure must then be simultaneously adjusted to give appropriate ion generation and electron current density. In the low-temperature case, if an external source is available to initiate the process, a low-voltage discharge mode may eliminate the need for the third electrode.

In all cases, long-time operation has been hindered by lack of good materials. Vacuum converters have achieved efficiencies of about 5% at power densities of $^1/_2$ watt/cm^2, with cathode temperatures around 1500 K and lifetimes of 500 hr. However, the cathode-anode spacings cannot exceed about 10 microns. Vapor-filled diodes, with 5-mil spacings and cathodes operating near 2000 C, have achieved efficiencies of 14–15% with power densities of 12 watts/cm^2 with lifetimes up to 600 hr. The three-element tubes have lower power densities, of the order of 3 watts/cm^2. Low-temperature tubes operating in the discharge mode have reportedly obtained power densities of about 5 watts/cm^2.

Solar Cells. In the solar-cell area, galium arsenide cells have now been prepared which exhibit 14% efficiency. This material may exhibit somewhat better performance than silicon for space applications, particularly with reference to high-temperature operation with concentrators. Other important research efforts have focused on vacuum deposition of silicon layers, as a possibly cheaper and better-controlled way of producing solar cells, and on methods of improving radiation resistance. One may expect considerable advances on both fronts. A spectrally reflecting solar concentrate for photovoltaic solar cells should increase performance to 65 lb/kw—a substantial improvement over the 150 lb/kw of today's noncon-



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Summary of U.S. Dynamic Space Power System Developments

Table prepared by George W. Sherman of AFSC Aeronautical Systems Division

Title	Type	Rating	Agency	S.F.C. #/Hp Hr	Specific Weight	Working Fluid	Duration, Hr	Status
Snap 2	Nuclear	3 kw(e)	AEC		250#/kw	Hg	10,000	Ground tested
Snap 8	Nuclear	30 kw(e)	AEC & NASA		47#/kw(e)	Hg	10,000	Component development
Spur	Nuclear	300 kw(e)	USAF		10#/kw(e)	K	10,000	Conceptual design completed
15 kw	Solar	15 kw(e)	USAF		65#/kw(e)	Rb	10,000	Initial component fabrication
Sunflower	Solar	3 kw(e)	NASA		250#/kw(e)	Hg	10,000	Development testing initiated
Stirling Engine	Solar	3 kw(e)	USAF		170#/kw(e)	He	10,000	Prototype under test
Dynasoar	Chemical	30 hp	USAF	1.5		H_2	250	Initial design and component test
Integrated Power-Cooling System	Chemical	15–40 hp	USAF	1.5	150#*	H_2	36	Prototype reader for test
Cryhocycle	Chemical (300 F)	8 hp	USAF	1.5	80#*	H_2	300	Initial design nearing completion
871A	Chemical	40 hp	USAF	4	150#*	N_2H_4	50	Final design nearing completion

* Not including tank and fuel.

centrating solar panels.

Magnetohydrodynamic Generators. Today MHD generators appear much more promising than they did a year ago. There are two reasons for this: Development of "hard" superconductors such as Ni_3Sn whose critical field may be as high as 100,000 gauss (thus making such strong fields available without excessive copper losses), and improved understanding of nonequilibrium flows. Since the power density of a MHD generator is proportional to the square of the magnetic-field strength, a very strong magnetic field will, of course, reduce the over-all dimensions of the generator. Also, nonequilibrium phenomenon with short recombination times may become usable (that is, "frozen-in" ionization after a sudden drop in static temperature). However, Hall effects become more important as the magnetic field grows, so that one would expect the geometry of future generators to differ appreciably from present designs. In any event, materials problems may be appreciably reduced through the use of some form of nonequilibrium phenomena (which may or may not be steady state).

For carefully controlled gas mixtures (those involving a noble gas as a carrier), a steady-state but nonequilibrium condition may arise in which electrons are heated well above the neutral and ion temperature through the action of the internally generated electric field. In this fashion, various experimenters have obtained the same conductivity at around 2000 K as one would expect from equilibrium conditions at 3000 K.

Fuel Cells and Batteries. Hydrogen-oxygen fuel cells now operate with current densities approaching 400 amp/ft.[2] The goal of much research is still, however, an ambient-temperature hydrocarbon-air cell. Much work remains to be done in this direction. The main problems to be solved are: (1) Electrocatalysis of a hydrocarbon fuel, (2) mass transport, particularly at the air electrode where one must supply oxygen and scavenge nitrogen, and (3) operation in an electrolyte capable of rejecting CO_2.

Battery Performance

Hermetically sealed nickel-cadmium batteries are being used widely in space vehicles, and their contemplated use is increasing. They are capable of thousands of repeated cycles, and have an energy output of about 12 watt-hr/lb. Sealed silver-cadmium cells are also being used because of their higher energy-to-weight ratio (25 watt-hr/lb) and nonmagnetic properties, but they are not as far developed, nor do they have the cycle life of nickel-cadmium cells.

Where the duration of the mission is relatively short, primary batteries such as mercury cells (35 watt-hr/lb), and silver-zinc cells (60 watt-hr/lb) are being used. In some contemplated applications, silver-zinc cells can be cycled several times. Research and development is in progress, attempting to develop sealed silver-zinc cells capable of many cycles of operation in space.

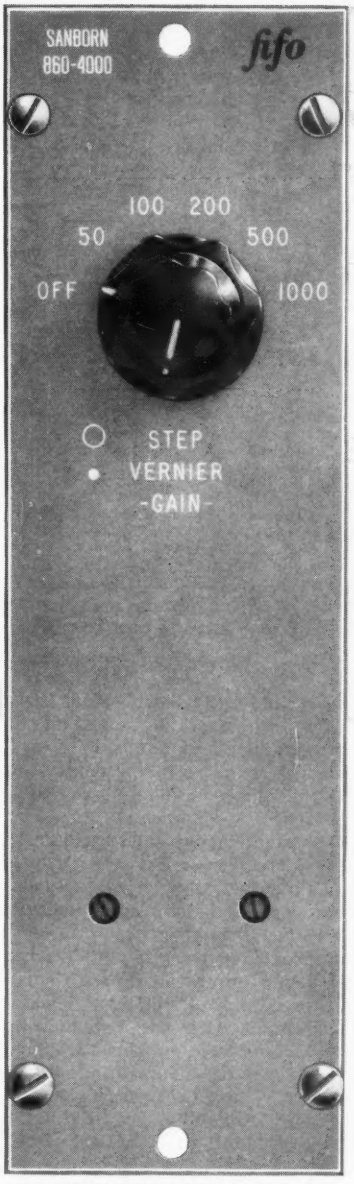
In general, in the field of space batteries, continued effort is being directed at improvements in the engineering aspects of producing reliable sealed cells, and basic research is being directed toward finding possible new high-energy, high-density rechargeable systems.

Dynamic Systems. Research and development efforts devoted to advancing the state of the art in dynamic engines for space power have been oriented primarily to the modified Otto cycle, the open turbine cycle, the Stirling cycle, and the Rankine cycle. The Brayton- and Otto-cycle engines have been developed for open-cycle operation with chemical fuels. Major work related to the Stirling and Rankine cycles has been devoted to closed-cycle power systems utilizing solar or nuclear-fission energy.

High-efficiency (70%) reciprocating expanders utilizing expanding hydrogen or combustion gas to generate power are under investigation. The chemically fueled APU is expected to have application for controlled manned re-entry vehicles which require both hydraulic and electrical power in the range of 5 to 200 kw for operating periods of a few minutes to a few hours.

The state-of-the-art work related to the Stirling closed cycle is devoted principally to a 3.8-kw engine. The engine itself has operated successfully at predicted efficiencies of about 32%.

All current programs for developing long duration (200 to 10,000 hr) dynamic engines for space power systems, which include orbital testing, are based on the Mercury-vapor Rankine engine. The Mercury-vapor engine at power levels below 5 kw is in advanced development; and 500-watt Mercury engines have made endurance runs up to 2510 hr and have been operated in simulated launch conditions with accelerations up to 10g; 3-kw Mercury engines have been



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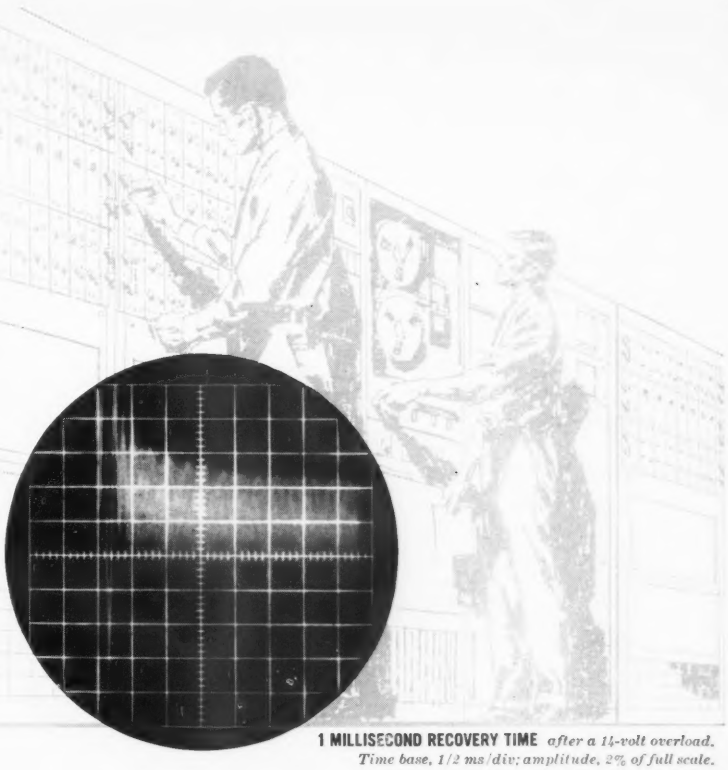

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Acknowledgement

The author wishes to thank the members of the ARS Power Systems Committee upon whose summaries this paper is based.

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Propellants, Combustion

(CONTINUED FROM PAGE 49)

peared on this subject. It is not easy to make final decisions at this time regarding questions of storability. Many factors are yet to be defined, and we still have insufficient knowledge of space environment. However, important factors such as those relating to the rate of loss of fuels by evaporation, the effect of various high energy radiations on propellant properties, and the effect of exposure of propellant to very high vacuum are being given attention. This latter problem is of most importance in connection with the potential applications of solid propellants. There has been some attempt to classify various liquid-propellant systems according to their storability, but at this time exercises of this type are of limited value.

Another propellant system which has received particular attention during the past year is the concept of a tri-propellant. The system of oxygen, hydrogen, and beryllium, for example, is one of the highest performing conceivable chemical systems (Isp of 453 sec at 1000 psi and sea-level expansion). The system of hydrogen, fluorine, and lithium has also been considered in attempting to make a decision among systems of this type and in comparing these systems with bipropellants such as H_2-O_2 and H_2-F_2. Factors of importance in making a choice between these systems cannot be quantitatively evaluated reflecting the present limited state of knowledge in some areas. Further work is necessary before it is possible to make a reasonable estimate of the percent of calculated performances which might

be expected in an actual engine test for systems containing exhaust components that can condense. The problems are associated with our lack of knowledge of the efficiency of combustion that might be realized and with the performance losses which are associated with two-phase flow. The effect of sealing factors on the performance losses must also be determined. At the ARS Solid Propellant Rocket Conference at Salt Lake City, considerable progress was reported on more quantitative calculation of the losses associated with the two-phase flow process, such as particle lag. The work of J. R. Kliegel of Space Technology Laboratories was particularly significant. The important problem of determining the relative loss resulting from combustion inefficiency as compared with two-phase flow has not been satisfactorily determined experimentally. Work is underway in various organizations in an attempt to analyze quantitatively the rocket-exhaust products of metalized systems. Such data combined with the determination of energy losses and an overall energy balance should lead ultimately to a more quantitative determination of the loss mechanisms. One factor which is often overlooked in making performance comparisons in metalizing systems is the affect of changing the expansion ratio on specific impulse. Very little data is available either theoretically or experimentally for the proper comparisons of propellant performance as a function of the expansion ratio in systems containing large amounts of condensibles.

Structural Problems Gain

As the size of solid rockets has risen to many feet in diameter, there has been a growing realization that solid propellants must be considered as having a structural interaction with the rocket. A comprehensive engineering analysis of the problem is contained in a GALCIT publication (California Institute of Technology) by M. L. Williams, P. J. Blatz, and R. A. Schapery. A problem of special importance in connection with solid motors larger than 8 ft in diam concerns the physical limitations of the propellant and propellant liner. The need for defining these propellant properties and predicting the mechanical performance of large solid-propellant rocket motors has been recognized for some time. Essentially, what is required in meeting the goals of a program of this type is the definition of the mechanical properties of the heterogeneous highly filled viscoelastic material. Thor Smith of Stanford Research Institute has made many contributions to this problem, and a group

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under the direction of J. H. Wiegand of Aerojet-General has also investigated the problem extensively.

In addition to defining propellant properties, it is necessary to establish a means of practical analysis of stresses in solid-rocket motors. Based on information obtained from the careful study of the nature of a composite propellant, a decision was made by P. G. Blatz of CalTech that the stress analysis should first be based on time-dependent properties, taking into account, however, nonlinearity and anisotropy. He in turn made a significant contribution toward this type of analysis by showing how to handle the nonlinear problem. Other work included an evaluation of the anistropic characteristics of the propellant. Experiments are underway to check the theoretical predictions experimentally for both thermal cycling and pressurization.

In the field of combustion research there has been progress in a number of areas. A few highlights will be mentioned.

Studies of the combustion-instability problems associated with the use of both liquid and solid engines is continuing. L. Crocco and his Princeton Univ. co-workers have succeeded in clarifying some of the velocity effects in linear instability and have begun studies on nonlinear effects using a shock-wave model. Also, Priem and co-workers at the NASA Lewis Research Center have made a noteworthy contribution by solving the nonlinear transport equations for a rocket combustor. The results permit prediction, for the first time, of perturbation magnitudes which will produce unstable operation and the equilibrium amplitude which will result. The NASA-Lewis experimental program has made substantial progress in clarifying the kinetics of the processes which can produce the perturbations involved in the theory: Jet shattering behind shock waves, drop ballistics, vaporization rates in oscillating flows, and oscillatory heat transfer. Acoustic instability in the transverse modes of solid-propellant rockets has been described in terms of acoustic loss and gain mechanisms by J. F. Bird, F. T. McClure, and R. W. Hart of the Applied Physics Laboratory, Johns Hopkins Univ. The treatment provided a better insight into the effects of particle damping as a function of particle size.

Interesting combustion investigations reported by H. G. Wolfhard of Thiokol Chemical's Reaction Motors Div. include low-pressure flame studies of a premixed hydrazine-diborane flame, the development of tracer techniques permitting study of local burning conditions in an operating solid engine, and the development of a new technique for studying the afterburning of rocket-exhaust jets with air.

An extensive amount of work is being done in the detonation field. At the ARS Propellants, Combustion, and Liquid Rockets Specialists Conference in Palm Beach in April, S. J. Jacobs of the Naval Ordnance Laboratory discussed the state of knowledge on the problem of detonability of propellants. And at this meeting, A. Macek of Atlantic Research Corp. discussed the transition to detonation and the interpretation of detonation tests. There has been considerable progress recently in the study of gaseous detonation. Very striking results have been obtained by A. K. Oppenheim, A. J. Laderman, et. al. using flash schlieren photographs. The development of detonation in a $2H_2$-O_2 mixture with pilot-flame ignition was studied. Exceptional detail was obtained in the photographs, revealing gas-wave dynamic aspects of flame acceleration which lead to the formation of a detonation wave.

These examples of progress during the year are not all-inclusive, but they do reflect major interest areas and indicate a few of the more significant advances. ♦♦

Ramjets

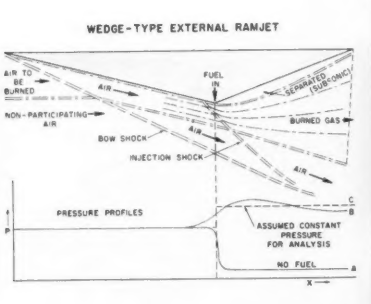
(CONTINUED FROM PAGE 49)

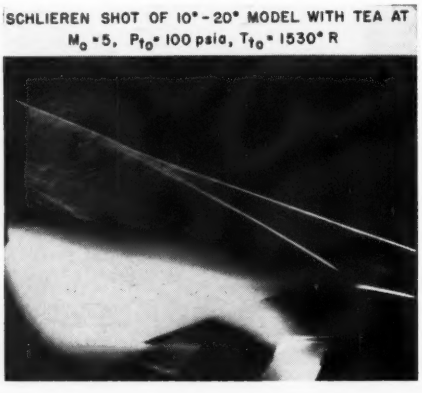
design and performance have not been released.

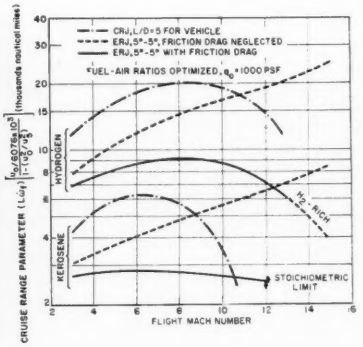
While the Typhon weapon system is under development, anti-aircraft protection of the fleet will be provided by the Talos and Terrier missiles in combination. The Talos system was installed on the Long Beach, a nuclear-powered cruiser, in September 1960. Three additional cruisers to be equipped with Talos systems are on the ways—the Albany, Chicago, and Columbus.

Progress in ramjet propulsion for missile use is not confined to American developments. In France, Nord-Aviation, S.A., fired Vega No. 15 to a speed of Mach 4.06 and an altitude of 96,500 ft on October 10. This launching was part of its over-all program with the Vega to explore propulsion by air-breathing engines and vehicles employing such engines at Mach numbers between 3 and 5 to altitudes of 115,000 ft. Ultimate application of the Vega would be in the surface-to-air missile category, since it has a present payload capacity of 330 lb and a range of approximately 250 mi. Vega No. 15 was previously fired under designations Vega No. 1 and Vega No. 9, and earlier attained Mach 3.7 at 79,000 ft. Nord-Aviation looks forward to entering a new phase of its ramjet efforts by exploring propul-

Studies of the External Ramjet by G. L. Dugger







sion at Mach 5–7 and possibly higher as part of its policy of collaborating with American companies and other institutions. Nord-Aviation is the developer of the experimental aircraft, "Griffon," the world's only manned aircraft employing a dual-cycle turbojet/ramjet powerplant. The Griffon has flown in excess of Mach 2 at 60,000 ft in a climb.

A number of extremely interesting research investigations and evaluation studies were reported during the year. Of major importance was the publication of the Symposium on High Mach Number Air-Breathing Engines, sponsored by AGARD and held at Milan in April 1960.[2] The papers presented evidence of the feasibility of developing air-breathing engines with flight capability to satellite velocity. Aircraft or missiles equipped with such engines were estimated to be able to deliver satellite payloads at a small fraction of present costs and to have an impressive superiority in economy over recoverable rocket schemes. Major results of the meeting were as follows:

1. Analyses showing the superiority of supersonic combustion for hypersonic propulsion.

2. Experimental and theoretical evidence for high diffuser kinetic energy efficiency at Mach numbers up to about 10.

3. Focus of emphasis on hydrogen as a preferred fuel for hypersonic applications.

4. Selection of the following technical programs as being most necessary to provide a capability for practical hypersonic flight: Experimental studies of supersonic combustion, including fuel injection, mixing, and reaction kinetics; studies of boundary-layer behavior in the hypersonic regime, under correctly simulated conditions of pressure, temperature, and Reynolds number; optimization of thermal protection systems, including aerodynamic design, insulation, cooling, and high-temperature materials; provision of static and flight-test facilities for hypersonic propulsion.

5. A decision that transport aircraft would operate most efficiently at speeds in the range Mach 5 to 8 where range in excess of 6000 mi. would be attainable. A combination of turbojet and ramjet propulsion would be employed.

6. Last but not the least, the need for recognition by civilian and military planning groups that the potentialities of air-breathing systems warrant a much larger financial support for R&D in this field.

Most of the current programs in hypersonic propulsion are classified, but interest in this work in the U.S. was amply demonstrated by the large audience that secured admittance to a classified session on this subject held at the ARS-IAS Joint Meeting in Los Angeles in June.

Unclassified work on the following topics during the past year has come to my attention.

Studies have been made by Frick and Strand of recoverable air-breathing boosters for satellite payloads that would employ a first-phase hybrid engine, a second-phase ramjet, and a third-phase H_2-O_2 rocket.[3] The study showed that "whereas one stage will just reach orbit for a ramjet cutoff velocity of 13,000 fps (M = 12), two stages will place nearly 12% of the takeoff weight into orbit."

A short description by E. Perchonok of engines for hypersonic flight which employ two new cycles—called Lace for "liquid air cycle engine" and Nulace for "nuclear liquid air cycle engine"—will appear shortly.[4] These engines use liquid hydrogen to condense air entering the engine inlet. The liquid air is then pumped into a conventional rocket engine, where it reacts with hydrogen. In Nulace, the nuclear reactor is used to preheat the hydrogen to add energy to the cycle with no additional propellant expenditure.

The only reported experimental studies that are known to the writer describe work by G. L. Dugger on the external ramjet engine (ERJ).[5] This engine involves injection of fuel at the apex of a flat-topped wedge in a high-Mach air steam, as indicated in the diagram on page 102. Ignition, burning, and expansion of the burned gases occur on the rear surface of the wedge, thus providing thrust and a lift force. The Schlieren photo on page 102 shows operation of this simplest of all engines in a Mach 5 air stream. Such an engine would surpass the performance of a conventional ramjet at speeds above about Mach 10, as indicated in the graph on page 102. Dugger also presents data on ignition delays in hydrogen and air systems for inlet temperatures in the range 1670–1860 R.

Finally, impressive progress toward the development of nuclear-ramjet propulsion was demonstrated during the summer of 1961 in the successful operation of the Tory II-A reactor at the Nevada Test Facility of the AEC.[6]

In conclusion, encouraging progress has been made during the past year toward the realization of the major gains possible in conventional flight application and in space-booster performance by use of air-breathing systems. Adequate financial support of this work could insure an early application of hypersonic air-breathing engines for civilian and military uses.

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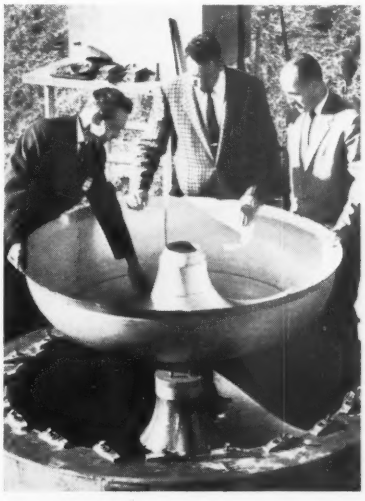
Formed with a Bang

Martin Co. engineers examine a metal torus explosively formed from a welded preform. Explosive forming can reduce the number and length of welds required in a conventionally made piece greatly. Martin-Baltimore is developing explosive-forming techniques for making missile and space-vehicle structures, and expects to reach production processes within a year.



National Plan for Atmospheric Sciences To Be Proposed

A task force of 150 American Meteorological Society scientists has met to recommend goals and outline a national plan for atmospheric science during the next 10 years, and will report on their activities in the "AMS Bulletin."

Communications

(CONTINUED FROM PAGE 37)

to permit optimum detection and in the use of coding techniques to improve efficiency.

Considerable ingenuity is being shown in the development of digital-data encoders which are optimum for a variety of particular applications. The theoretical maximum communication efficiency as defined by Shannon is being very closely approached. Digilock, for example, is operational and in production; it has been demonstrated to come within 1 db of predicted performance.

Communication Satellites. The past year has seen much activity on communication satellites per se and on space-oriented communication systems in general. Following the successful Echo experiment of last year, the actual mechanization of several communication satellite systems, both passive and active, has been initiated. Among these are the AT&T system, Hughes' Syncom, Project Needles (West Ford) and NASA's Project Relay.

Of special significance has been the establishment of a national policy in this area defined by the President. This announcement has cleared the air politically and otherwise for private industry and world governments to get on with what may very well be one of the truly significant contributions of space technology.

Implanted Telemetry. Successful experiments have been conducted in the past year with animals that show the practicality of full implantation, wiithin the body, of certain kinds of instrumentation and associated transducers. Telemeters for measuring internal body parameters, such as temperature, stomach acidity, and blood pressure, at relatively inaccessible points are being developed as fully implanted devices.

At least one organization (Correlated Data Systems, Inc.) has progressed on a technique for remotely recharging the battery of a fully implanted telemeter, resulting in a device with, potentially, an indefinite lifetime.

Lasers. Light amplification through stimulated electromagnetic radiation (the Laser) has received considerable attention in the past year by a number of organizations and has been shown to be technologically feasible. The possibility, through Lasers, of developing a source of coherent light is significant for a number of reasons. Perhaps the most important of these for the immediate future is that it opens up a whole new electromagnetic spectrum for use in communication systems. Coherent light (light whose frequency spectrum is confined to a very narrow band and whose phase, amplitude, and frequency can be accurately determined and measured) can be modulated with intelligence in the same fashion as electromagnetic radiation in the radio and microwave regions of the spectrum. Laser systems are being studied for their possible advantages in both underwater and deep-space communication systems.

Problems. There are several significant areas where the state of the art urgently needs to be advanced. Problems are pressing; in some cases, they are actually retarding the whole area of space technology:

1. Improved ground-station netting techniques (more reliable communication and synchronization systems required).
2. Improved biomedical instrumentation.
3. Improved techniques for extreme range measurements (multimillion mile).
4. Improved rocket-engine test stand instrumentation (for example, for measuring more accurately the total impulse of a rocket motor, especially with solid motors). ♦♦

Spectral-Line Intensity Tables

The first extensive tables of relative spectral-line intensities on a uniform energy scale have been prepared at the National Bureau of Standards. Data are presented over the wavelength range from 2000 to 9000 A for the 70 chemical elements most commonly encountered by spectrochemists.

Guidance and Control

(CONTINUED FROM PAGE 39)

ponent density. It became more practical to consider digital techniques which use large numbers of components.

Inertial instruments received a significant improvement through the development of high-quality floated bearings and air-bearings for use on the output axis and high-quality isoelastic ball bearings for the spin axis. Solutions were found to the difficult problems associated with torques, signal generators, materials, manufacturing, and assembly.

New radar and tracking systems based on Doppler and phase comparison were perfected for missile guidance and range instrumentation. Telemetry was perfected to the point that nearly all in-flight failures could be properly diagnosed.

For the most part, development has followed a rather steady improvement, with each generation of hardware containing some improvements over the previous. Although the flight-test programs have served to locate some weak points in design, equipment has performed in flight pretty much in accordance with the expectations of its designers, which can be considered a tribute to the excellent techniques used for analysis, synthesis, design, simulation, and laboratory testing.

Today's state of the art finds us still on the upward curve. The emphasis today is on still more miniaturization with improved performance and higher reliability. In addition, there are some new devices and systems under development to meet the requirements of future space missions. A considerable effort is also being put into radically new approaches, such as cryogenic gyroscopes, electrostatic gyroscopes, and microminiaturization through thin-film techniques. For tracking and communicating over the vast distances encountered in space missions, larger and more efficient ground antennas equipped with better receiving equipment are being installed.

In past years, the approach to the guidance problem was largely governed by the severe limitations of the existing guidance hardware. The relatively simple solutions utilized were often quite satisfactory for the missions being undertaken at the time. Now, owing to the complexity of the missions being considered, greater emphasis must be placed on devising guidance schemes which are optimum solutions from the performance standpoint. The available digital computing techniques using more reliable miniaturized components makes it profitable to apply much more sophisticated guidance schemes to obtain optimum performance within the constraints set by such things as propulsion, aerodynamic heating, acceleration loading, radar look-angle, etc. Powerful mathematical methods are being brought to bear on this problem, and a solid theoretical foundation is

developing on which to base the design of future systems.

One of the basic requirements of the guidance and control engineer is a thorough knowledge of feedback theory. The guidance and control system consists of many devices which contain servo systems. These servo systems are combined to become components of larger servo systems. Finally, the vehicle itself becomes part of a large feedback system which contains the vehicle aerodynamics, the propulsion system, the thrust-vector control system, and the guidance system.

The interconnection of all these devices and systems, each having certain gains, phase shifts, resonances, tolerances, and nonlinearities, provides the designer with a very difficult problem which can be solved only through a very thorough analytical study. He seeks to define by analytical models the parameters involved, and he studies these models through complex analog and digital simulation techniques. After the hardware has been specified, designed, and built, he connects together as much of the hardware as is practical for additional simulation, using analytical models as required to substitute for the missing devices and the aerodynamics, propulsion, and structural characteristics.

This field has seen tremendous advances in recent years. To meet the demands, universities have introduced courses which prepare their graduates to enter such work. Analog and digital computers have become generally available, and a vast amount of experience has been accumulated in the application of these machines to the solution of the analytical problems. The net result is, that even in the face of the increasing complexity of the vehicle and the mission, today's designer can send a new vehicle to the launching pad with a considerable degree of confidence.

Field Gaining Depth

One of the most significant characteristics of the state of the art is the almost routine manner in which complicated new problems can be solved. From the large number of experienced people engaged in this work, from the advanced techniques being applied, and from the results we are getting, one must conclude that this young field has attained a degree of maturity. Even so, the rate of growth of our capabilities in this field is high, and the future advances promise to be as impressive as those of the recent past.

Although the propulsion engineers talk in terms of millions of pounds, and the structural engineers describe configurations of fantastic proportions, the size and weight of guidance and control equipment are still a matter of great concern, especially that portion of it which must be carried throughout the entire mission. Redundancy, which is one of the approaches to reliability, is difficult to apply at present due to the added size, weight, and power consumption; but it may become more practical if the equipment can be sufficiently miniaturized. Although man, himself, may in some respects help to improve the reliability of a system through his ability to assess the situation and take shrewd corrective action in case of a malfunction, the placing of man in a space vehicle will establish a much higher over-all reliability requirement.

Miniaturization is the order of the day. It is being pursued vigorously on all fronts. Gyros, accelerometers, gimbal systems, servo motors, synchros, actuators, optics—all have been subjected to a shrinking operation in re-

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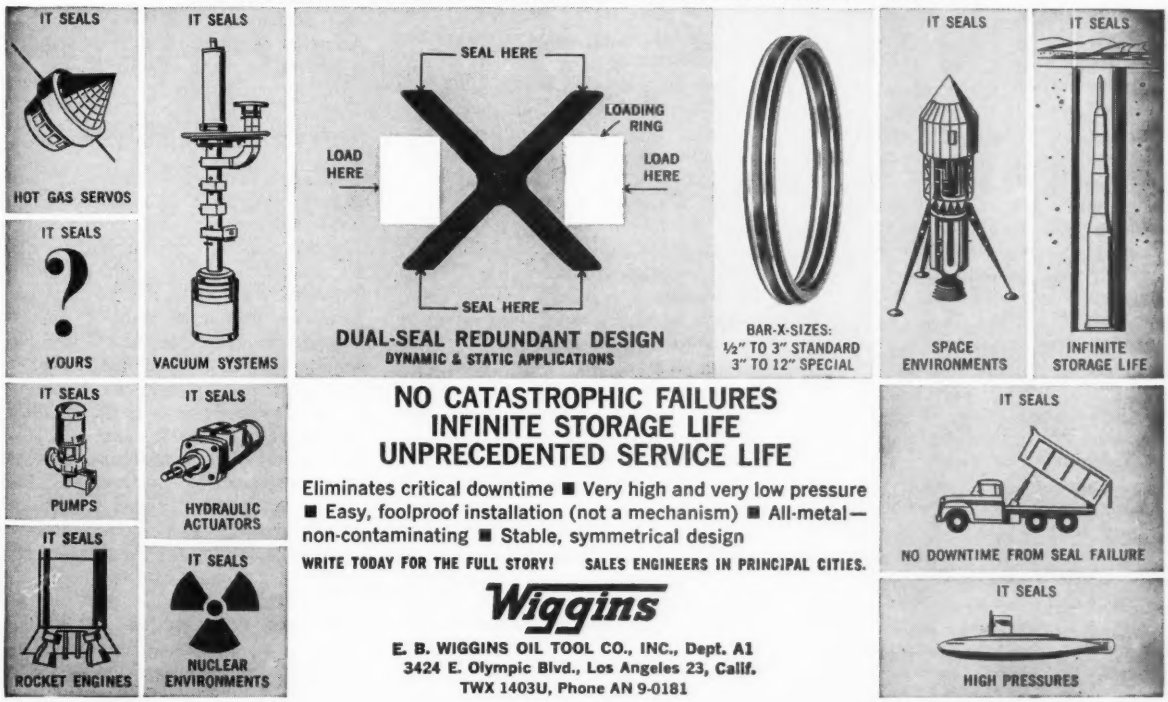

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cent years. Performance has been maintained, or even improved. In looking at today's designs, one wonders how much further it will be possible to go without some basic change in concept.

Perhaps the most striking improvements in miniaturization have been in the development of high-density electronic packaging techniques. Printed circuits provided an initial breakthrough and will continue to find many applications. In some areas, however, a new technique is being applied in which the components are stacked together cordwood style to form dense modules and the interconnections are made by welding. This technique, as described in an excellent booklet published by the Sippican Corporation, promises to find wide application in vehicle-borne equipment.[1] Already excellent, this method of packaging will see additional improvement as better welding machines and components having more suitable lead materials become available.

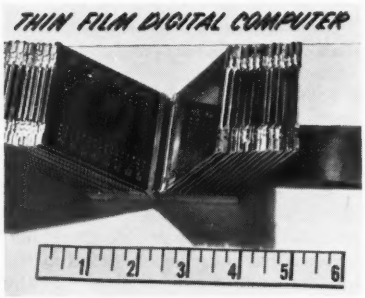
Thin Films Advance Art

New techniques are being perfected which involve the manufacture of components *in situ* by the deposition of thin films on ceramic substrates. This concept promises orders-of-magnitude size reduction as well as improvement in reliability. Although not yet widely applied, we can at least observe that today's state of the art permits serious consideration of these techniques for equipment presently in the design stages.

In the future, the manufacturers of guidance and control equipment will find that reducing the cost will become a more important factor than in the past, even in the face of demands for more reliability and higher performance. Although excellent in many respects, today's guidance and control systems are extremely expensive, adding considerably to the total cost of the vehicle. Less-expensive systems of good accuracy and small size might open up some new possibilities for small, inexpensive short- to medium-range missiles.

An interesting problem is developing in the thrust-vector control field. With the high flame temperature of modern solid-propellant motors and the extreme motor size required for space missions, it appears that new techniques for thrust-vector control should be developed. One technique under development is the injection of liquid or gas into the nozzle so as to produce deflection of the thrust vector.

Today's customer finds himself faced with a bewildering array of components and systems being presented by a large number of firms, each



The introduction of thin-film techniques promises spectacular reduction in the size of digital computers, as indicated in this development by Hughes.

claiming certain superior features for their products and presenting increasingly larger amounts of statistical data to support their claims. This intense competition has undoubtedly been partially responsible for the rapid improvement in the state of the art. However, it is hard to see, from the manufacturing standpoint, how the large guidance and control industry can continue to thrive on the somewhat limited number of missiles and space vehicles being built, which indicates that it is probable that in the future an increased effort will be put into the further development of such other markets as commercial and military navigation systems for ships and planes. Many concerns will find that the capabilities they have developed will put them in a good position to enter other still expanding markets, such as medical, scientific, and industrial devices.

This year the ARS held its first National Conference on Guidance, Control, and Navigation at Stanford Univ. Over 800 specialists attended and participated in sessions at which approximately 75 papers were presented. Since this meeting was apparently very successful in allowing specialists to get together for an interchange of technical knowledge, plans are being made to have another specialists meeting at an eastern location in 1963.

The past year has seen a multitude of significant contributions by a large number of different organizations. Many new components and system developments have been announced and not a few have been successfully demonstrated. The report which follows attempts to list some items of interest which have come to the attention of the author, mostly through information furnished by the organizations involved. No claim is made for completeness, and it is recognized that many significant contributions have been omitted either through oversight or lack of information. Accordingly, the author wishes to apologize beforehand to any organizations which find that they have been omitted or inadequately mentioned.

During the past year, the Navy deployed its Polaris A-1 submarine-launched missile. An improved version, the Polaris A-2, has been successfully flight-tested. Whereas the A-1 uses jetevators on both stages for thrust-vector control, the A-2 uses jetevators on the first stage and rotating nozzles on the second stage. The development of a further-improved A-3 model has been announced which will utilize fluid injection for thrust-vector control of the second stage and will employ a new miniaturized inertial-guidance system. Lockheed is prime vehicle contractor, and the guidance systems were designed by MIT.

Honeywell announced further development of their electrically suspended gyroscope. A. Nordsieck, in a paper delivered at the recent ARS Guidance, Control, and Navigation Conference, described some of the principles of such a gyroscope.[2] T. Buchhold in a paper at the same conference described General Electric's work on cryogenic inertial systems, and J. T. Harding of JPL presented a paper describing the cryogenic gyroscope.[3-4]

Lear has called attention to their development of the "Norlac" north-seeking gyro, which they claim has brought to mobile missile systems alignment accuracies normally associated only with fixed launching sites. The fully tactical model weighs 145 lb with tripod and electronics, has an accuracy of 15 sec of arc, and requires a time to fix north of only 15 min, including run-up time.

Computer Techniques Used

Using a completely automatic computer technique to optimize the parameters, Kearfott has designed a Size 5 synchro which, together with a Size 5 servomotor and a motor-generator, provides a matched line of high-performance miniature rotating electromechanical components. They also announced the development of a new inertial-navigation accelerometer which they believe to be the smallest, lightest, most accurate unit available today. Also of considerable interest is their work on pneumatic-digital-computer elements, which would permit construction of a digital computer having small size, low weight, and low cost.[5]

In keeping with the growing demands for miniaturization, Hughes has constructed a digital computer of extremely small size based on the use of thin-film techniques. The results of

laboratory experience with their microelectronics techniques indicate that an exceptional degree of reliability can be obtained.

As a follow-up to their development of the Mark I stellar-aided inertial-navigation system for the Snark missile, Nortronics has developed a series of advanced "Astronertial" systems having application to ballistic missiles and space vehicles. These devices feature reduced size and weight, increased reliability, 24-hr star-tracking capability, and minimum ground-support equipment.

The difficulties associated with spin-axis ball bearings in precision gyros have led to the development of self-generating air bearings by Minneapolis-Honeywell, Autonetics, and others, which demonstrate some significant advantages but require exceedingly close mechanical tolerances.

Litton, which is in volume production of inertial-reference and navigation systems for manned aircraft, has announced the completion of a series of sled tests on an inertial system for missile applications. The company claims that the exceptionally small size and weight as well as high performance of their system will make it a major contender in the missile-guidance market.

The successful first test of Minuteman in February was an example of how a complex multistage vehicle, complete with all its guidance and control equipment, can be developed in the laboratory and made to work the first time. Boeing is prime contractor, and the guidance system is supplied by Autonetics.

The Pershing missile has, in the past year, racked up an enviable flight-test record, proving the performance of its guidance and control system. Martin-Orlando is the prime contractor, and the guidance system is supplied by Bendix.

Further flight-testing of the Atlas missile has demonstrated an exceptional performance of the Arma inertial-guidance system over ICBM ranges. The string accelerometers used in this system are a departure from the more conventional instruments used in other systems.

The Redstone missile, produced by Chrysler with guidance and control supplied by Ford Instrument, has entered the final phases of its existence with a spectacular performance as booster for the first two Mercury manned space flights. In spite of its early vintage, the Redstone has served as the basis for our entry into space by launching the first American satellite and the first American man in space.

Although incomplete, this list of accomplishments indicates that the past year has been a busy one filled with many new and interesting developments. The next year promises to unveil more new devices and systems presently in the planning stage.

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Electric Propulsion

(CONTINUED FROM PAGE 39)

vaporization, which makes the space storage problem extremely severe. Even for hydrogen, long-time storage in space is not yet satisfactorily solved, particularly when radiation absorption from an onboard nuclear reactor is involved.

Major research efforts are directed toward a better understanding and control of heat transfer and of recombination. Both effects have a direct influence on power efficiency. The amount of heat transferred to the chamber and nozzle walls depends greatly on details of the gas flow, on the shape and length of the arc, and on the method of nozzle cooling. Intimate knowledge of the exchange of energy and matter between the three arc regions, and between the arc and the surrounding gas, will be necessary for an optimum thrustor design. Satisfactory analysis of this problem has not yet been accomplished. Further research and development work will undoubtedly lead to more efficient arc thrustors.

Arc engines operated with alternating current are even more difficult to analyze because of the rectification properties of arcs, and because of the possibilities of multiphase interaction.[3] An advantage of a.c. arcs is the fact that stable operation can be achieved with negligible ballast resistance.

Several arc-jet thrustors have been under development during the past year. An engine model for 1 kw, developed by Plasmadyne Corp. under NASA contract, will be flight-tested late in 1962.[4] The photo on page 108 shows the thrustor with heat shield, electric starting circuit, hydrogen tank for 40-min operation, and flow-control equipment. The engine provides a specific impulse of 1100 sec at a power efficiency of 38%. If operated with ammonia, the same thrustor would provide I_{sp} of 780 sec at 24% power efficiency.

A 3-kw unit was built and tested at Avco Corp.[5] With hydrogen as propellant, the engine provides I_{sp} of 900 sec at 40% power efficiency. A thrustor of this kind is planned for flight testing on a Scout vehicle during 1963.

Large Thrustors Efficient

Larger thrustors are inherently more efficient because of the more favorable volume-to-surface ratio. The photo on page 108 shows a 30-kw d.c. engine built by Avco under NASA contract. This radiation-cooled engine can be operated with hydrogen or ammonia.[6] Hydrogen provides an I_{sp} of 1000 sec at 38% efficiency and an I_{sp} of 1350 sec at 41%. These efficiencies lie between those computed for frozen and equilibrium flow. When operated with ammonia, the same thrustor provides an I_{sp} of 1000 sec at an efficiency of 40%. These figures show that specific impulse and power efficiency are by no means simple functions of the molecular weight of the propellant. The temperatures on the external surface of the 30-kw nozzle, as measured with an optical pyrometer, were 1600 K at an I_{sp} of 1000 sec with hydrogen and 2600 K at an I_{sp} of 800 sec with ammonia.

A three-phase a.c. thrustor for 30 kw is presently being developed by General Electric under NASA contract. The unit is regeneratively cooled by a flow of hydrogen around the nozzle wall. So far, an efficiency of 45% at an I_{sp} of 1100 sec has been obtained.[7] The photo on page 108 shows the operating thrustor.

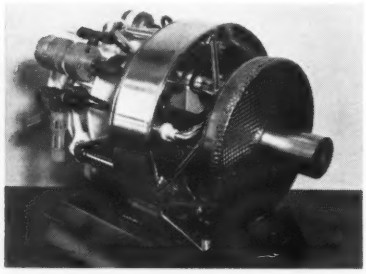
Another 30-kw engine, operating on d.c., was built by Plasmadyne under an Air Force contract. This thrustor achieved efficiencies up to 55% at an I_{sp} of 1000 sec with hydrogen.[8] Ducati at the same company obtained specific impulses up to 2000 sec with experimental units, but the power efficiency was not greater than about 20%.[9]

While the useful application of arc-jet engines had been under question for some time, a definite requirement for this kind of propulsion system appears now to be established. E. Dangle of NASA Goddard Space Flight Center recently described a number of planned arc-jet applications for satellite-transfer missions and for satellite orbit correction.[10]

Ion Engines. Ion engines consist of four major components—propellant storage and metering system, ion source, acceleration system, and beam-neutralization system. Propellant-handling systems will be basically similar in all three forms of electric propulsion. They must be capable of delivering accurately controlled propellant flows of less than 1 milligram per second to several grams per second, depending on the thrust level and specific impulse. The corrosive nature of some of the probable propellants, such as cesium and mercury, has prompted research studies of their metallurgical properties. Propellant feed can be achieved by positive displacement or by temperature control of a boiler. In the latter case, the output pipe may contain a porous barrier with wetting surface which allows vapor to pass through but retains the liquid phase.

The accel-decel principle in the ion accelerator finds more and more acceptance. It allows a high beam current density, and yet a conveniently low ion-exhaust velocity. The hump of potential between the accel and the decel portions is even mandatory to prevent neutralizing electrons from flowing upstream into the ion source. Unfortunately, accel-decel systems have an inherently poorer ion-optical quality than simple accel systems, and they are more subject to ion interception. Impinging ions come from two major sources: (1) Poorly focused ions from the ion source itself and (2) ions produced in the accelerator by charge-exchanging collisions of ions with neutral atoms which have escaped from the source because of its imperfect propellant utilization. This effect is a major stimulus to the achievement of high propellant efficiency. The impingement of high-energy ions on the electrodes leads to sputtering of electrode material and to eventual loss of optical quality and of integrity of the accelerator.

Design of efficient, low-interception ion-accelerator systems has reached a considerable degree of sophistication. Analog-computer evaluation of two-dimensional electrode configurations using electrolytic tanks, electron-beam analogs, resistance networks, and other systems has been perfected by several organizations.[11] One efficient ion-optical system designed in an electrolytic tank has a demonstrated ion interception of 10^{-4} to 10^{-5} of the primary beam.[12] Rapid digital-computer programs are now available for self-consistent calculation of space charge and ion trajectories in arbitrary two-dimensional electrode systems.[13]

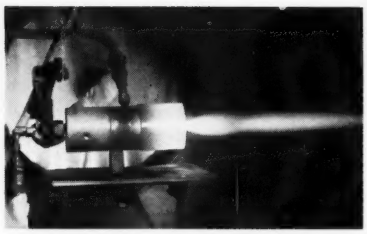


Plasmadyne's 1-kw arc-jet engine—showing the thrustor, heat shielding, electric starting circuit, and feed systems—to be flight-tested in late 1962.

Significant and encouraging progress has been made on the neutralization problem. During 1959, this subject began to attract widespread theoretical interest. When experimental results began to appear, it became apparent that a broad beam of ions under steady-state conditions would proceed down a long tank without excessive divergence or ion turnaround, even without any intentional means for neutralization. Transient measurements showed, however, that the establishment of beam neutralization took as long as several milliseconds and that neutralization was undoubtedly accomplished by secondary effects occurring at the walls of the test tank. Whether neutralization could be achieved in the space environment was a burning question, and opinions ranged from optimistic to pessimistic.

Neutralization Experiments

During the past year, improvements in equipment and short-time measuring techniques have led to more advanced experiments on the neutralization of broad cesium beams.[14-15] The results greatly improved the understanding of the neutralization process, and they stimulated confidence that neutralization can also be accomplished in space. The cesium engine used consisted of a porous tungsten button 1 in. in diam and an accelerator grid at a spacing of $^1/_{10}$ to $^1/_{20}$ in., providing the essential high-perveance "broad aspect ratio" beam. Experiments were conducted in a 7-ft-diam vacuum chamber with an ion transit path up to 10 ft long. The ion collector was segmented to allow measurements of beam divergence. A fine wire grid shielded walls and collector from electrostatic fields arising within the volume of the chamber. The grid also suppressed stray electrons, while offering negligible impedance to the flow of ions. The behavior of the system was studied by abruptly switching the potential of the cesium emitter to its positive accelerating voltage and by observing the various electrode currents immediately thereafter. The calculated transit time of the ions



Avco 30-kw laboratory model of a d.c. arc-jet thrustor.

General Electric 30-kw laboratory model of an a.c. arc-jet thrustor.

along the 10-ft path at the voltage applied was 140 microsec.

When the electron source was cold, the ion current initially exhibited the "turnaround" effect, that is, returned to the accelerator grid. The collector current rose slowly, reaching its full value only after 0.02 sec. During this period a strong negative current was observed to flow from ground to wire grid, indicating the presence of large positive-ion space charges within the volume of the chamber. Oscillations occurred during the first part of this period.

When the electron source was heated to emission temperature, the ion current to the collector rose abruptly to its full value at a time precisely 140 microsec ($\pm 2\%$) after the beam had been switched on. It should be noted that, because of the grid, the collector current meter could respond only to ions which had reached the last inch of their trajectories. The current from the electron emitter, by contrast, rose to a value equal (but opposite in sign) to the ion current within 1 microsec after the time when the beam was switched on. Negligible currents were observed to flow to the wire grid, indicating that the net space charge within the volume of the chamber was less than 0.1% of the total ion charge within the volume. After 140 microsec, the current from the electron source fell rapidly to a value close to zero. From that time on, the common form of neutralization due to secondary wall effects began to prevail in the chamber.

These experiments are believed to represent active simulation of space

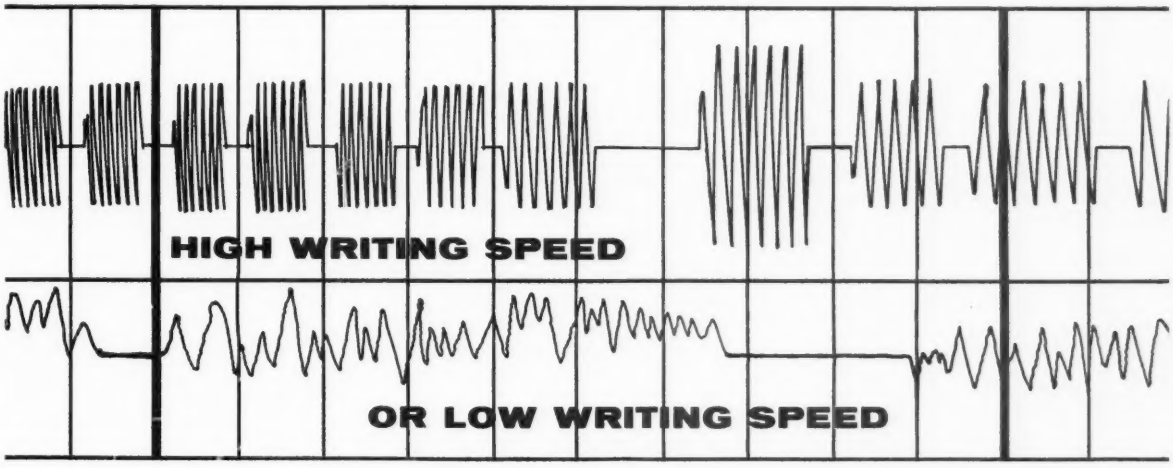
conditions during the first several feet of passage of a freshly started ion beam. The ions have not had time to reach the walls, and the electrons are shielded from the walls. The walls, therefore, could influence the beam only through electric fields. But these, as measured by the grid current, were shown to be of negligible influence. These results, underscored by the dramatic contrast in behavior between the neutralized and un-neutralized beams, appear to give promise concerning the feasibility of neutralizing a broad ion beam by electron injection in space. In addition, the experiment represents a marked advance in techniques of space simulation in the laboratory.

Several basic types of ion sources are under vigorous and progressive development. The most widely utilized ion source is still the contact, or surface-catalyst, type, in which cesium vapor is ionized after contacting a hot (1100 C) tungsten surface. The ion current is withdrawn by an accelerating field. Spraying cesium vapor onto the tungsten surface from the downstream side is under investigation by several groups. However, propellant efficiency and electrode interception make it desirable that the cesium be introduced from the rear by passing through pores. Initial problems of fabricating plenum chambers for the cesium feed, of bonding porous tungsten to the plenums, of obtaining porous tungsten with proper pore size (about 1-micron diam), suitable density (about 85%), and sufficient strength, and of providing efficient heaters for the tungsten, have been solved to some extent. Brazing techniques have produced suitable bonds for small ($^1/_4$-in. diam or less) porous buttons, but in larger structures thermal stresses and migration of the braze material are still causing difficulties. Electron-beam welding has been successful for larger porous plates. A number of existing applied research programs are intended to produce solutions to these materials problems. Voltage breakdown in cesium atmospheres, and the effects of sputtering of various propellants on different electrode materials, are also under investigation at several laboratories.

Major cesium-ion engine development programs are underway at Hughes Research Laboratory under NASA contract and at Electro-Optical Systems, Inc., under AF contract. Both efforts are directed toward engines capable of being tested in space late in 1962. The work at Hughes has to date reached the following status: The engine produces a 3-in.-diam hollow beam with 0.05-in. wall thickness at the engine exit. Thrust of the expected magnitude has been demonstrated at an accel-decel ratio of 2:1, an acceleration voltage of 10.6 kv, an I_{sp} of 8900 sec, and a beam current of 45 milliamp. The perveance of this engine is 41×10^{-9} amp volt$^{-3/2}$ (41 nanoperves). Electrode erosion after 23 hr of operation was negligible. Design thrust and perveance for the flight test engine, shown on page 110, are somewhat higher.

The latest operating data of the Electro-Optical Systems ion engine are classified. The last unclassified data, obtained in June 1961, referred to a device consisting of 61 apertures of $^3/_{16}$-in. diam in a hexagonal array.[16] Cesium-ion currents up to 120 milliamp and thrust of several millipounds were reported for operating times close to 300 hr. The perveance of this device was 14 nanoperves per aperture. Work has continued, and operating levels are now considerably higher. The photo on page 110 shows a flight-model prototype based on this concept.

Successful programs on cesium-ion engines, though on smaller scale, are



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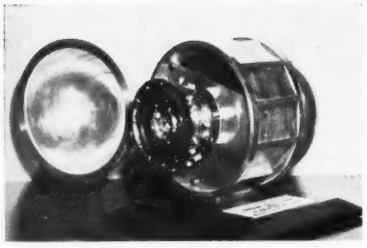
underway at Space Technology Laboratories, Rocketdyne, and Lockheed, and significant contributions have been made by these groups. The NASA Lewis Research Center described a cesium contact-ionization engine with a 0.3- by 6-in. slit beam, designed specifically to reduce heat losses. Power efficiencies of this engine have exceeded 70% at an I_{sp} of 8700 sec.[17]

A second type of successful ion source is an electron-bombardment device in which high-energy electrons from an arc or glow discharge, confined to a narrow region by a magnetic field, produce ions by collision with propellant atoms. An ion beam is extracted from the resulting plasma by an electrostatic acceleration system ("duoplasmatron" design of von Ardenne). Mercury-ion currents of several amp-cm^{-2} have been obtained by Goodrich High Voltage Astronautics; adequate beam shaping and accelerating systems are presently under development.[18] Thompson Ramo Wooldridge has reported very promising results for a considerably modified duoplasmatron.[19] Employing a representative linear section of a future annular source, propellant efficiencies up to 90% were obtained with argon at a total source energy expenditure of about 600 ev per ion, compared with a few thousand ev for surface-ionization sources. Operation with mercury has demonstrated comparable results. Current densities of several hundred milliamp cm^{-2} were measured; at an I_{sp} of 5000 sec the power efficiency was 73%. The maximum arc voltage with mercury is less than 20 volts, which insures that ion energies will remain below the threshold for sputtering. This in turn promises extended source lifetimes.

NASA-Lewis Device Promising

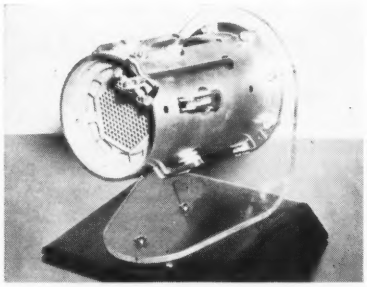
A third very promising bombardment engine is the low current density device developed by the NASA Lewis Research Center and shown in a photo on page 112. It utilizes a less-intense magnetic field and a much larger extraction area than the duoplasmatron-type sources. Power efficiencies of the order of 60% at an I_{sp} of 5000 sec and of 70% at 8000 sec have been achieved. A 1-amp beam has been extracted at an I_{sp} of 7100 sec from a 20-cm-diam source, the corresponding calculated thrust being 33 millipounds. A flight version of this engine, developing a thrust of several millipounds, will also be space-tested in 1962. As in all of the electron-bombardment sources, the electron-emitting filament has a relatively short lifetime. The accelerator structure of the NASA-Lewis ion source is expected to have a lifetime of about 1000 hr, while the filament life will be only about 150 hr.[17] Other groups which are investigating bombardment ion sources include Aerojet-General and Oak Ridge National Laboratory.



Hughes hollow-beam cesium-ion engine and prototype capsule for space test in late 1962.

A very interesting ion engine, the oscillating-electron engine, has been the subject of considerable experimental and theoretical work during the past year.[20] A potential field is generated to keep the electrons trapped, and the ions expel at the rate at which they are produced by electron-atom collisions. When leaving the potential field, the ions are accompanied by an equal number of electrons. By this process, the ion beam is neutralized from the beginning, and neutralization problems do not exist. While theoretically the outlook for this engine is very favorable, more experimental work may be desirable before an appraisal can be made.

Plasma Engines. Most of the plasma propulsion devices under active investigation fall into three major categories—pulsed plasma accelerators, crossed-field accelerators, and traveling-wave accelerators. The pulsed plasma devices, which come in a variety of forms, rely on the interaction of a pulsed magnetic field with a pulsed current.[21] The magnetic field is produced by the primary current returning through an external circuit, or it is a pinch-producing effect of the gas-discharge current. The T-tube, button gun, and rail gun utilize a return-current-produced magnetic field.



Electro-Optical Systems, Inc., prototype of a flight-model multiple-beam cesium-ion engine.

Their geometries are such that rapid decoupling of the plasma and the field occurs. The conical gun has a longer interaction time; acceleration is caused by a rapid pinch and by the divergence of the aximuthal magnetic field. The so-called "pinch engine" utilizes curved electrodes to change the motion of a toroidal pinch discharge from purely radial to axial. Since interaction with the electrodes is the only mechanism which produces the change in flow direction, severe electrode erosion must be expected. As the motion becomes primarily axial, the discharge resembles that of the conical gun.

A promising pulsed device is the two-stage coaxial gun in which the magnetic field acts only in the desired exhaust direction. Auxiliary fields or collision processes to force the plasma into axial motion are not necessary. An externally triggered low-power discharge is followed by a high-power, self-triggered discharge which gives the desired plasma acceleration. Encouraging preliminary experimental results have been obtained.

Device Comparisons Difficult

A meaningful comparison among the various pulsed accelerator experiments and an appraisal of their suitability for space operation are virtually impossible because of the wide variations in test conditions, the lack of definitive measurements, and the difficulty of extrapolating from single pulse operation to repetitive pulsing. Some of the devices have demonstrated promising specific impulses, others have shown good efficiencies, and several have been operated for extended periods. However, comparative performance data cannot be established yet for any of the devices. Groups working on these systems include General Electric, Lockheed, General Atomics, GM's Allison Div., Republic Aviation, and Los Alamos Scientific Laboratory.

Crossed-field accelerators are steady-state devices.[22] A conventional arc jet drives a partially ionized plasma through a channel across which a magnetic field and an electric field are impressed perpendicular to each other and perpendicular to the flow direction. The $\vec{j} \times \vec{B}$ force then continuously accelerates the plasma. In some experiments a small amount of cesium or another alkali is "seeded" into the plasma upstream of the channel. At the plasma temperature (about 7000 K) the cesium is completely ionized, and the conductivity is thereby increased. The NASA Langley Research Center, Northrop, MHD Research, and other organizations are presently engaged in crossed-field-accelerator research. Experimental results tend to be consistent, and in the low-specific-

impulse range (1400 sec and less) they appear to be of practical interest. Thrusts in the range of 0.2 to 3 lb were obtained with nitrogen, argon, and air at over-all efficiencies between 30 and 70%. The high efficiencies are encouraging, but they are expected to decrease with increasing specific impulse because of back voltage in the accelerator chamber.

Although the crossed-field accelerators produce relatively high thrusts with simple power supplies, they suffer from several serious problems. Severe erosion of electrodes and wall material limit their lifetimes. Loss mechanisms, such as current bypass in various regions, thermal losses in the boundary layers, and Hall-effect flow deflection, keep power efficiencies relatively low.

It has been stated that, in general, an efficient accelerator must operate at high Mach and Reynolds numbers. If boundary-layer losses are considered, it appears advantageous to employ a small ratio of channel length to cross-section dimension. If breakdown is induced by the applied electric field, boundary-layer losses must be treated in a different manner due to localization of the current path, and the optimum ratio of channel-length to cross-section dimension may change. Also, the magnetic field and the plasma conductivity should be high, although there is some indication that thrust and efficiency go through a maximum with increasing magnetic field.

Traveling-Wave Accelerator

Traveling-wave accelerators utilize a moving, recurrent magnetic field which accelerates an ionized gas by electromagnetic interaction.[23] There are three basic methods of producing this moving field in the external coils: (1) A polyphase resonant radio-frequency circuit capable of giving a smooth traveling field; (2) a delay line which gives the desired velocity of propagation; and (3) a series of timed, pulsed ringing circuits. The ions in the plasma are too massive to be appreciably accelerated by the magnetic field, which will not be stronger than about 600 gauss. It has been verified by measurements that the magnetic field acts only upon the electrons, which thus separate sufficiently from the ions to generate a strong axial electric field. This field in turn accelerates the ions. The self-generated, pinching magnetic field then forces the plasma into neutral toroids which are found to be remarkably stable during acceleration. Heavy working fluids are desirable. Argon and mercury have been employed to date at driving frequencies of 25–500 kc. Specific impulses of 2500–12,000 sec were obtained. Plasma densities are on the order of 10^{12}–10^{13} cm^{-3}, which implies few interparticle collisions and complete ionization.

Several loss mechanisms exist in these devices. Gas heating, which occurs during the ionization process, is difficult to evaluate because of the nonequilibrium conditions, but it is assumed to consume about three times the power needed for ionization. Joule heating of the gas, caused by current flow during the acceleration process, is of minor influence only. Joule heating of the magnetic coils by skin effect can be reduced by proper design. Wall-impingement losses can probably be kept small by proper magnetic confinement, but one attempt to accomplish this with a d.c. axial magnetic field caused excessive decoupling of the plasma from the driving fields. Future efficiencies of traveling-wave accelerators could be as high as 80%, provided the plasma can be made to travel in the magnetic cusps such that

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it will encounter less difficulty in leaving the magnetic field. Traveling-wave accelerators are under study at Litton Systems, Avco-Everett, NASA-Lewis, the Naval Supersonic Laboratory at MIT, and other places.

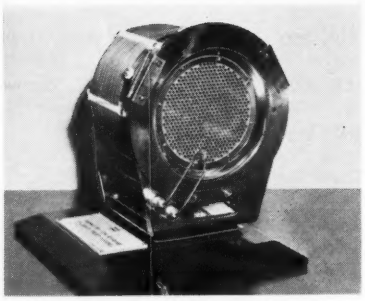
The general outlook for electromagnetic propulsion devices is promising. It is true that they depend on sophisticated power-input schemes or heavy, separate d.c. magnetic fields; but they have already demonstrated useful thrust levels in realistic specific-impulse ranges and at relatively good efficiencies. A great deal of detailed diagnostic analysis remains to be carried out, experiments must be performed at even higher specific impulses, and, most importantly, much better understanding of the basic processes must develop through experimentation and theoretical studies. The danger of excessive erosion must be overcome, and the masses of heavy components, particularly d.c. magnets, must be further reduced.

Flight-Test Programs. The flight testing of electric propulsion systems under real space conditions, a much-discussed subject in 1960,[1] became a firm project this past year. Four engine models are under preparation for space testing in late 1962—a cesium-ion engine by Hughes, a mercury-ion engine by NASA-Lewis, a cesium-ion engine by Electro-Optical Systems, and a hydrogen arc-jet engine by Plasmadyne. The thrust levels of the engines will be of the order of a few millipounds.

Flight-Testing Readied

A flight-test capsule, developed by RCA under NASA contract, will accommodate two engines per flight, the necessary instrumentation and communication equipment, and a battery power supply with converters for roughly 1-kw power output. The capsule will be launched into a near-vertical trajectory by a Scout vehicle. With a peak altitude of almost 5000 mi. and a total flight time well over 1 hr, each engine will have a test time of about 35 min under space conditions. The first Scout will carry a Hughes engine and a NASA-Lewis engine, while the Electro-Optical Systems and the Plasmadyne engines will be tested on the second Scout.

In 1963, flight testing with Scout vehicles will continue. It is expected that advanced models of the first four engine types, and also new models from other developers, will be space-tested during 1963 and the following years. Testing on satellites may begin late in 1963 with power supplies like Snap II and Sunflower. Present plans call for the satellite testing of 30-kw electric-engine models in combination with a Snap VIII nuclear-electric power supply from 1965 or 1966 on.



NASA-Lewis low-density ion engine of the electron-bombardment type for the 1962 space tests.

The early Scout flight tests will provide direct measurements of engine thrust through the change in spin rate of the capsule. In addition, a number of measurements will be taken of voltages, currents, propellant-feed pressures, temperatures, ion and electron densities, beam spreading, neutral efflux, and vehicle potential. A number of research studies have been underway during this past year with the objective of defining measurements and instruments for a meaningful engine diagnosis during operation in space. It is of great importance that reliable correlations between space and laboratory measurements be established even during the early phases of the flight-test program.

A development and flight-test program for electric propulsion systems is underway at the AF Wright Air Development Div. While this program has some features similar to the NASA program, the two programs actually complement and support each other. Technical details of engine design, diagnostic beam measurements, and methods of thrust determination differ characteristically. Both programs together will provide faster and more expedient progress of the new technique of electric propulsion than one program alone.

Mission studies for electric propulsion systems continued during the past year. Arc-jet systems, even in combination with Snap III power supplies, are attractive for the transfer of satellites from low to high orbits and, except for attitude control, for the fine correction of orbital parameters. Ion engines will be useful for small payloads to the vicinity of planets, for out-of-the-ecliptic flights, and for other deep-space missions.

Of particular interest will be manned flight to Mars. With a realistic projection of present technologies into the 1970–1980 period, it can be shown that electrically propelled vehicles will not take longer to travel to Mars than vehicles with chemical or nuclear propulsion and that payload ratios will be four- or five-times greater than those of nonelectric counterparts.

The progress of electric propulsion during 1961 has substantially increased confidence in this new rocket technique. It should be expected that the design of mission-oriented, high-performance arc-jet and ion engines begins around 1963 or 1964. The requirement for appropriate nuclear-electric power supplies will arise in 1965. It is anticipated that the 30-kw Snap VIII power source will enter its space-testing phase in 1965. In view of the long development times required by nuclear-electric space power systems, it cannot be emphasized too strongly that the development of larger power supplies of advanced design should be initiated *now*. There is no doubt that the pacing element in electric propulsion during the 1965–1980 period will be the electric power source.

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Liquid Rockets

(CONTINUED FROM PAGE 43)

failures, and, consequently, added expense have been brought about by liquid-propulsion systems. The legitimate question also arises, are these incidences likely to multiply in the clusters of engines which will be required to boost the large payloads envisioned? To assess such questions more effectively, an attempt will be made to evaluate the impact of some recent developments in the liquid-rocket field.

While other classifications might be made, it appears that three sorts of difficulties still plague the liquid rockets in development and in flight use. A problem of long standing has been that of combustion instability. Another has been the complexity of control systems, which has led to unreliability. A third problem has involved tank pressurization. Recent developments indicate that satisfactory solutions are being found for these problems.

The difficulty in approaching combustion instability analytically is notorious. So, wherever instability did occur in the development of a rocket motor, it had to be eliminated by an empirical approach involving changes in the injection system, special limitations on the starting cycle, and similar adjustments. This process often increased development cost and time. It might be mentioned parenthetically, however, that the empirical procedures have almost always led to successful results, and combustion instability as such has usually been responsible for the development delays rather than for actual flight failures. At the last ARS Liquid Rocket Specialist meeting, encouraging reports were given on means of controlling instability more effectively.[4] While the details of this work have not yet been made public, and need further verification, engineers are confident that development delays due to high-frequency instability will be less troublesome in the future.

The control system will profit from this. Some special timing requirements can be dropped, and this will indirectly foster a simplification of controls. Further control simplifications are obtainable if the designer will emphasize reliability rather than performance. For example, the vehicle structure should be sufficiently strong to withstand at least modest excesses in thrust, such as are likely to occur in the starting cycle. Attempts to avoid such excesses invariably increase the complexity of controls, and generally lead to a less-reliable system. The fact that a rocket engine proper can operate reliably and satisfactorily with simple controls has been established by the H-1 engine of the Saturn cluster as well as by the Titan II engines. It now remains to design the remainder of the vehicle systems to be compatible with simplified controls, so that full advantage can be taken of this possibility of improved reliability.

As to pressurization systems for tanks, even turbopump-fed rockets require some tank pressure for operation. It has been found that these systems are often unreliable and lead too frequently to holds in the countdown and even to flight failures. Now progress has been made in simplifying pressurization systems by pursuing two different approaches. One involves the so-called autogeneous system. As reported at the ARS Space Flight Report to the Nation,[5] the Titan II missile uses its own propellants and products of combustion to pressurize the tanks. Thus the extraneous gas bottles, regulators, and valves are eliminated.

Lowering Tank Pressure

A report on the second approach was also given at the SFRN. This consists of the inclusion of booster pumps in the propellant system to obviate the necessity for high tank pressure—to a degree that the propellant vapor pressure alone may in fact suffice.[6] Thus, both cryogenic and storable propellants are believed to be adaptable to the elimination of troublesome components, and therefore to an increase in reliability. It should further be mentioned that a purely pressure-fed rocket system, on the other hand, obviating the necessity for any rotating machinery, may also be of advantage in certain applications. For example, the Able and Able-Star rockets may be cited, both of which have established an enviable record of reliability.

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provements at hand in the three problem areas, significant increases in reliability may be expected.

The prime interest of those directly concerned with liquid rockets is, of course, in latest developments and their possible effects on the scope of application of these rockets. By continually focusing one's attention on these new advances, however, it is easy to lose sight of some of the basic features of liquid rockets and to leave out of consideration facts which seem so familiar that they are almost considered to be platitudes. These basic facts have to be clearly kept in mind in charting the course for the future development of liquid rockets. A clear understanding of these facts is also a prerequisite for assessing the areas of application of liquid and solid rockets, a subject which has been given considerable attention in the recent past. For these reasons the authors feel that it may be allowable to devote a part of this progress report to the recounting of some of the well-known fundamental features and potentialities of liquid rockets.

One of the most obvious and basic aspects of the liquid rocket is the fact that the propellants do not form an integral part of the combustion chamber and that they can be stored outside the combustion chamber. This allows the separation of the combustion problem from the storage problem, and makes it possible for the combustion vessel to be developed and designed independently of the storage vessel. Furthermore, again because of the nature of the propellant, no structural requirements are imposed on the propellants, and also propellants and tanks may easily be transported to the launch site separately.

Liquid-Rocket Features

From these fundamental characteristics, many other features of the liquid-propellant rocket follow:

1. Because the hot combustion gases are not in the proximity of the storage vessel, the latter needs no special protection against high temperatures, and it lends itself to a lightweight construction.

2. Because of the lack of structural contact between propellant and storage vessel, storage over a wide range of environmental conditions can be accomplished more easily.

3. Because only those propellants react which are introduced into the combustion chamber, the rate of thrust can be controlled by controlling the propellant flow. For the same reason, operations can be cut off precisely, and restarts are possible.

4. Because the propellant may be used as a coolant, liquid rockets are suitable for long operating times and at high total impulse.

5. Because the engine is not affected by the operation, the unit can be tested repeatedly simply by replenishing the propellants.

6. Because of the very few restrictions that are placed on liquids by structural requirements, the liquid rocket engine is most suitable for use with a wide variety of propellants, in particular, high-energy propellants, and propellants that can be stored for extended periods of time.

This enumeration indicates the many favorable characteristics of the liquid rocket. The liquid rocket should therefore be outstandingly suitable to meet—economically as well as technically—a large variety of requirements.

Versatility Double-Edged

Indeed, liquid rockets have been developed for many different applications. But, in a most paradoxical way, their inherent versatility has worked to their disadvantage rather than to their advantage. A few examples may illustrate how this illogical state of affairs has come to exist. Since liquid propellants are suited for yielding high specific impulse, competitive pressure and customer demand have accorded a very exaggerated importance of combustion efficiency and specific impulse. Next, as the tanks and combustion chamber lend themselves to lightweight construction, extreme values of the loading fraction have been demanded; and because repeated testing of liquid rockets is possible, an exorbitant number of development or preflight tests has sometimes been requested. In general, there has been a rather strict insistence on specific performance parameters such as specific impulse, that is, parameters which can be easily specified numerically. Parameters such as reliability, ease of operation, and launching costs—which are probably of even greater importance but cannot be specified as simply numerically—have not received the proper emphasis. This does not mean that a high order of reliability and low cost have not been requested. It does mean, however, that there has been an unwillingness to relax the aforementioned performance parameters sufficiently to provide the prerequisites for a truly sound and workable system.

In future programs, the basically superior characteristics of the liquid rocket might be used to achieve higher margins of reliability, greater ease of operation, and fast launching times. Extreme accomplishments in specific impulse, for instance, might well be deferred to a later time. By following this approach, the liquid rocket may well become suitable for applications which had been regarded in the past as too complicated, too costly, or too difficult.

This change in emphasis, with its primary attention to reliability and simplicity, will be particularly applicable to the development of the "next generation" of large boosters. In the course of the systematic exploration of space and its use for civilian and military purposes, still larger boosters than those now contemplated will undoubtedly be needed. This "next generation" may well be based on single-rocket units delivering on the order of 15–20-million lb of thrust with a total impulse of several billion pound-seconds. Such units—or even clusters of such units—could serve as the first-stage booster for a variety of different space missions.

In booster applications of this type, performance parameters such as specific impulse and propellant-load fraction are not of critical importance, whereas reliability, ease of operation, and over-all cost per launch *are* the key features. By strong emphasis on the latter and by realistically curtailing the requirements for specific performance, there is little doubt that a most successful and serviceable booster can be developed. Again, it is most plausible that such a unit be based on liquid propellants, since even curtailed values of the specific performance parameters will be sufficiently high to give over-all effectiveness. As to the question of development, the liquid rocket has, as was mentioned earlier, the basic advantage that the combustion process can be treated independently of propellant-storage requirements. This possibility greatly facilitates the necessary experimental task. Indeed, this separation may be the reason for the fact that historically —with very few exceptions—every new level of thrust and total impulse has been reached first by a liquid-propellant rocket.

Potential Still High

To conclude, we can say that the state of the art of liquid-rocket engines and propellants is sufficiently advanced to provide the propulsion needs for an initial program of lunar exploration. Nevertheless, the potential of liquid-propellant systems have still not been fully exploited. In the past, emphasis has been placed largely on specific performance. By relaxing these requirements and shifting the emphasis to reliability and ease of operation, the liquid rocket may become most effective for applications considered outside its purview in the

past. Finally, a liquid rocket designed for simplicity and reliability will best meet the requirements for the next generation of space boosters.

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Magnetohydrodynamics

(CONTINUED FROM PAGE 43)

problem of heating and containment has now begun. The formulation of models of the phenomena, and the correlation and piecing together of the large number of experimental observations, forms the core of the present MHD. Every scheme for heating plasmas requires the conversion of electric energy into thermal energy. This irreversible heating of a gas is an old story in fluid dynamics. This is most commonly done in shock tubes in which the low-density, low-temperature gas is compressed and heated by gas pressure. MHD on the other hand has taught us how to use electromagnetic pressure to compress and heat a conducting gas.

MHD has made significant contributions to the formulation of the interaction between the gas-dynamic pressure of the plasma and the electromagnetic pressure which contains it. The formulations for the various containment concepts have proved extremely useful in estimating the stability of any given geometry and often indicated the possible remedies for instability or for reducing the loss of plasma by leakage. The controlled-nuclear-fusion effort has produced a number of configurations for heating and confining plasma, but the central idea is the use of electromagnetic fields produced either by currents in the plasma or in coils. The latter offers much greater flexibility but at the expense of weight and power losses. The discovery of materials that are superconducting at high field strengths has of course made the independently induced magnetic field very much more attractive.

The MHD problem in propulsion is the transfer of momentum from the electromagnetic field to the plasma. In generating electric power, the problem is the reverse; the kinetic energy of the plasma must be converted to electric energy. Most of the effort directed at the solution of the latter problem is being devoted to the study of boundary layers, flows, heat transfer, and erosion of the electrodes. A great deal of work is also being done on the study of the properties of plasma, such as its conductivity, degree of ionization, temperature, and other thermophysical properties. Perhaps the most important development in MHD is the realization that plasma behaves more often as a multicomponent fluid than as a homogeneous one-component fluid. When plasma is accelerated, the difference in the behavior of the electrons and of the ions is accentuated.

The existence of two very different components in a fully ionized plasma

Superconducting Magnet Demonstrated by Westinghouse Engineers

Engineers of Westinghouse research laboratories have demonstrated what they believe to be the first superconducting magnet—for its size, weight, and energy consumption by far the most powerful magnet ever built. The size of a doughnut and only a pound in weight, it develops a magnetic field twice as strong as would be produced by a conventional iron-core electromagnet as large as an automobile weighing 40,000 lb and operated to saturation—a flux density of 43,000 gauss. The Westinghouse device runs from an ordinary automobile storage battery pulling a few watts to overcome the small losses in the wires leading to the magnet.

This coil of glistening wire can develop a field of 43,000 gauss.

J. K. Hulm, associate director of the Westinghouse research laboratories, headed the team of scientists and engineers responsible for the new magnet. They included M. J. Fraser, Henry Riemersma, A. J. Venturino, and R. E. Wein. As Dr. Hulm says, the development of superconducting magnets will enhance considerably chances for the direct, large-scale generation of electric power; make possible a whole new generation of powerful atom smashers; increase the possibility of designing a magnetic "bottle" in which the vast energy of the hydrogen bomb reaction can be harnessed for useful power; and make more feasible some of the far-out methods proposed for long-distance space travel.

The Westinghouse magnet is wound from a half-mile of wire the diameter of a sewing thread. This wire consists of an alloy of the superconducting metals niobium and zirconium. It thus employs the finding by J. E. Kunzler and his associates at Bell Telephone Labs that certain superconductors retain strong magnetic properties.

About 5000 turns of the threadlike wire are wound into a coil, or solenoid, 2 in. in diam and $1^1/_2$-in. long with a $^1/_2$-in. hole in the center. The coil is immersed in a vessel of liquid helium, which keeps it at a temperature near −450 F. Although only three times the thickness of a human hair, the wire from which the coil is wound carries a current of 20 amp. At this current density, a scaled-up wire the thickness of a piece of chalk (one square centimeter) could carry 200,000 amp, or the total installed capacity of 2000 up-to-date homes in a town of 7000 people.

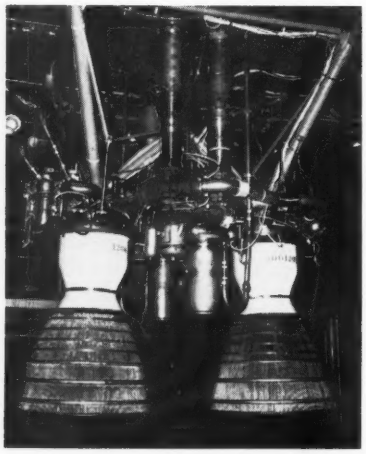
A key to success of the magnet, the wire was designed, prepared, and drawn by metallurgists at the Westinghouse research laboratories, the Westinghouse materials manufacturing department, Blairsville, Pa., and Armetco, Inc., Wooster, Ohio.

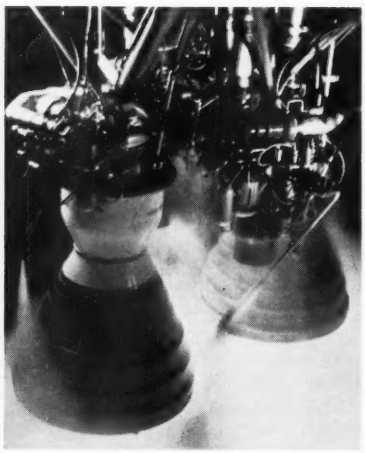
Dr. M. J. Fraser, who led the metallurgical research team that produced the superconducting wire, comments that this "first-try" magnet was just about as strong as the most powerful continuous-service magnets to be constructed in more than a century of electromagnet technology. Although considerable work remains to be done, he says there seems to be no fundamental metallurgical roadblock to the widespread development and use of superconducting magnets in the future.

is not a new discovery, but some of the implications are. The MHD theory is for the most part being developed as a theory of a one-component fluid, but unfortunately most of the experiments, and particularly those involving acceleration, indicate that the difference in the behavior of the electrons and of the ions cannot be approximated away. A much more successful correlation of the experimental information can be achieved on the hypothesis that there is a strong coupling between the electrons and the magnetic field and a weak coupling between the ions and the electrons. Ions move much more freely through a magnetic field than do the electrons. This fact has far-reaching implications for plasma accelerators. In fact, it is possible in principle to construct a d.c. electrostatic plasma accelerator by restricting the motion of the electrons by a magnetic field while the ions are accelerated by the electric field.

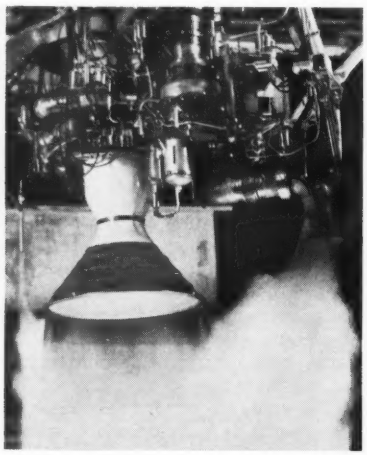
No evaluation of a theory can be complete without some statement as to its contribution to diagnostics. MHD has been used not only to correlate experimental observations but also to define them. It is all too easy to fall into the error of thinking that experiment and theory are separate, with the latter used mostly to add elegance to the experiment. A much more accurate position is that almost every experimental observation is defined only by theory. Consider even the simplest measurement, say, the velocity of a shock. It is theory that justifies identifying the motion of the luminous region as the motion of a shock. Therefore it can be said that MHD, in some respects at least, has matured to the point where a respectable number of experimental observations on the properties and behavior of plasma appear to have meaning. Meaningful measurements have been made on plasma temperatures, densities, instabilities, wave propagation, and oscillations. This is not to say that the meaning of these measurements is clear and unambiguous, but there is reason for feeling that the progress has been noteworthy. ♦♦

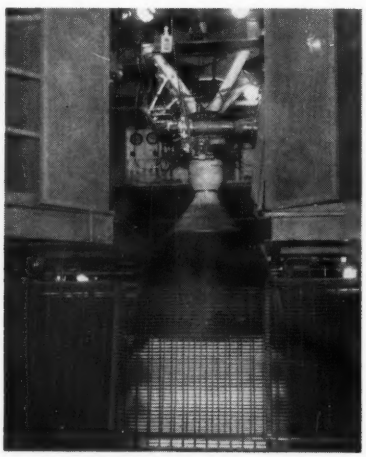
Titan II Engines in Action





Aerojet-General's engines for the Titan II missile have given rated performance, and the Air Force has announced that the dual-engine Titan II first stage develops 430,000-lb thrust and the second stage some 100,000-lb thrust at altitude. These engines burn the storable propellants nitrogen tetroxide and an even mixture of UDMH and hydrazine. (Titan I employs liquid oxygen and gives 300,000-lb first-stage thrust and 80,000-lb second-stage thrust at altitude.) Above, Titan II first-stage engines with testing rigs before and during a static firing. Below, second-stage engine firing with and without skirt, which would be added for high-altitude operation, extending nozzle area ratio from 13:1 to 45:1. Titan II will see service as a booster for Dynasoar and possibly in other space programs. Martin is prime contractor for Titan II, Boeing for Dynasoar.





Research and Development Moves Steadily Upward

Research and development done by private industrial firms in 1960 amounted to $10.5 billion, according to the latest report of the National Science Foundation, a 10% increase over the figure for 1959. Of the $10.5 billion, 58% was financed by the Federal Government. The NSF "Reviews of Data on R&D" covering 1960 (No. 30) can be obtained for 10¢ from the Supt. of Documents, U.S. Government Printing Office, Washington 25, D.C.

GRD Bibliography of Lunar And Planetary Research

A "Bibliography of Lunar and Planetary Research—1960," prepared by J. W. and L. T. Salisbury of the AF Geophysics Research Directorate, is available from OTS, Dept. of Commerce, as GRD Research Note No. 62. The 60-page report is annotated.

1962 NATO Fellowships Open

Some 60 NATO Fellowships worth $5000 each will be awarded citizens and nationals of the U.S. for science study abroad. The NSF will make the awards on the basis of candidates ability and need for advanced training in the sciences. Applicants must file with the NAS-NRC Fellowship Office, 2101 Constitution Ave., N.W., Washington, D.C., by Dec. 18, 1961.

(CONTINUED FROM PAGE 41)

but interrupted them for a number of years. In a recent article (*Znaniye Press*), Gazenko states, "At the end of the 1940's and beginning of the 50's, almost simultaneously in the Soviet Union and abroad, biologists were given the opportunity of carrying out experiments with animals during rocket flights into the upper layers of the atmosphere. Thereby, the basis was laid for planned training for human flight in space." Although the early USAF rocket flights showed excellent foresight and team approach to the solution of the problems (as can be seen from the monkey and rat flights in the Aerobee experiments), it is now apparent that the American bioastronautic programs lost significant ground in the years that followed.

The Russians continued experiments and consolidated the areas of space medicine, since their obvious "national goal" was "human flight in space." Gazenko states, "It was natural that biological experiments on rockets became the main experimental trend of space biology. Space biology and space medicine are entirely new fields of knowledge. They grew up and reached maturity in a short time, absorbing the achievements of biology, medicine, radio electronics, and other fields of natural science and of the exact sciences. Several fundamental problems confronted these new disciplines. The first problem dealt with the study of conditions and factors acting on the living organisms during flight, as far as possible, which might exert some harmful and unfavorable influence on it. If such factors exist, how is the organism to be protected against these effects? The *main* route of investigation for the solution of this problem consisted of direct experiments on high-altitude rockets and particularly on living beings in artifical earth satellites and spaceships."

The next area which the Russians considered important was the life-support system. Gazenko notes that "space biology had to work out systems which would assure not only the possibility of preserving life of any living organisms, including man, but also the conditions necessary for human work onboard the ship." It is clear, that from the early 1950's the Soviets chose space biology and space medicine as *prime national objectives*, and the lack of interruptions in these programs resulted in the successful orbiting of Laika and other animals. These paved the way for the Gagarin and Titov flights.

This philosophy still prevails, for when someone asked Yazdovsky, "Who would be first to the moon, a Russian cosmonaut or an American astronaut?" he replied, "Neither—It will be an animal."

In the U.S., there has been an unfortunate lack of recognition of the importance of bioastronautics. "Why man in space?" "We will do it with machines"—have been common spoken phrases. With the Apollo program having been made an American national objective by President Kennedy, there is no longer any doubt of the importance of bioastronautics.

It is gratifying to see that some positive steps are being made within the NASA and USAF to firmly establish the life sciences and bioastronautics as integral parts of their respective organizations. The recent reorganization within the NASA with the moving of the Life Sciences Office from a separate status to an integrated one, under the Office of Manned Space Flight Programs, with Brig. Gen. Charles H. Roadman as director of aerospace medicine, is significant. It is undertsood that an attempt will be made to eventually have life sciences incorporated in most of the research centers of NASA.

At present, a Life Sciences Laboratory exists at NASA's Ames Research Center under the direction of Webb Haymaker, who is also an assistant director of Ames. The NASA Space Task Group will move shortly to their new quarters at Houston, Tex., and will be called the "Manned Spacecraft Center," under Robert Gilruth. Lt. Col. Stanley White is presently chief of its Life Sciences Div. and will continue in this capacity. The increased emphasis on life sciences is noted by the enlarged staff that will serve Dr. Roadman and his deputy director, Al Mayo, in Director Brainerd Holmes' Office of Manned Space Flight Programs.

On the Air Force side, the AFSC has formed a separate Aerospace Medical Div. under Brig. Gen. Ted Bedwell. The headquarters of the division is located at San Antonio, Tex., and includes the Aerospace Medical Center and the world-famous USAF School of Aviation Medicine. Additional bioastronautic integration is expected to take place within the AF.

The Navy, private industries, and the universities also have excellent life-science capabilities, measured in highly trained personnel and facilities, which are presently supporting or could contribute to the national bioastronautic efforts. This tremendous American bioastronautics potential has not yet been recognized and organized to obtain full usefulness on a national basis.

Life Support. Today's requirement is simple and straightforward and certainly well within our state of the art —create and maintain a near-ideal environment for man in space. Many studies in America outline many approaches for this capability. This was a basic Russian philosophy at the beginning of their space program.

The Project Mercury life-support system has been amply covered in the literature and need not be repeated here. The Soviets decided at an early date to provide a sea-level, 14.7-psi atmosphere in a sealed cabin. Yazdovsky said they are using air with slightly enriched oxygen (21–29%). Some of the reasons given by Yazdovsky for their choice of an "ideal" terrestrial environment in space cabins can be summarized as follows:

1. Their experiments with helium proved to be discouraging, since helium leaked and disrupted voice communications.

2. Nitrogen is used since it is *not* an inert gas, and its physiological role in the body is still unknown.

3. In experience with low cabin pressure, one gaseous system (100% oxygen) was found *not* to be as simple and reliable as some believed; it increased the fire hazard and reduced reliability of the hermetic sealing of the cabin.

4. There was a desire to maintain a higher pressurization in order to give a longer decompression time in case of an accidental decompression. This would provide the cosmonaut with sufficient time to prepare himself for this emergency.

5. They concentrated on essentially two operational systems which would serve as backups to each other. The first system is a high-pressure gaseous system, using LiOH as the carbon-dioxide absorber. The other is a chemical regeneration system. They have found that potassium superoxide appears to be the best regenerative agent. Vostok II had a 10-day atmospheric and food reserve on board. The Russians apparently don't see any great advantage in the perfection of a liquid-oxygen system capable of operating in a weightless state, since the high-pressure oxygen systems have been perfected and the necessary reliability to insure flawless operation has been achieved. Although the Soviets experimented with sodium superoxide, they prefer the potassium. However, Yazdovsky mentioned that sodium superoxide can be used for water-vapor control.

6. Because of the possibility of a meteoroidal puncture of the hermetically sealed cabin, and the rapid oxi-

dation of the particle and wall structure, a 100% oxygen system was considered dangerous. This appears to be verified by the recent experiments by Thompson and Gell of Chance Vought, wherein particles at 28,000 fps were fired into pressure cabins containing an animal. In their experiments, 4000-frames-per-second photos showed the flash due to a 100% oxygen (5 psi) system, in contrast to the low elimination of a 14.7-psi air supply (21% oxygen, 79% nitrogen). The rapid oxidation in the 100% oxygen atmosphere resulted in extreme whole-body burns on test animals.

The USSR has been very successful in mastering the techniques of hermetic sealing, since cabin pressure has been maintained, without the loss of nitrogen. As a matter of fact, the sealing is so good that they are concerned about the accumulation of atmospheric contaminants, like carbon monoxide. Recently exhaled air from human subjects as a source of CO has been studied by Bogatkov, Hefedov, and Poletaev (in *Voennon-Meditsinskii Zhurnal*, February 1961). Yazdovsky was interested in American methods for disposing of CO in sealed cabins. He was told that a hot-wire catalyst oxidizing CO to CO_2 was the best method.

Their philosophy apparently has been that an ideal space-cabin environment is a prime design requirement in order to reduce the number of variables in the scientific experiment.

Weightlessness. The observations of Gherman Titov in regard to weightlessness were summarized in the October issue of *USSR Journal*. Titov stated: "I withstood the noise, vibration, and stress of the orbiting well. I was not dizzy or sick, and my consciousness, vision, and hearing were unimpaired. I worked from the very first moments, checking the instruments, maintaining two-way communication with the command post, and watching the receding earth through the portholes. I began to prepare myself for weightlessness, but it came smoothly after the last stage separated off. The first impression was strange, as though I were in the middle of a somersault and flying with my legs upward. This sensation lasted only a few seconds. When it passed, I realized that the ship had been orbited. The spaceship kept making its circuits. I had work to do. Once more I took the manual controls, this time with more confidence since I knew the ship would behave. And it did, like a well-trained animal. The schedule said I was to go to sleep. I was tired enough. Vostok II had made six circuits, and nine hours of the space flight had passed. Also, the long period of weightlessness had begun to affect my vestibular system and I had unpleasant sensations from time to time. At 6:15 p.m. the ship was passing over Moscow. It was the time scheduled for sleep. The receivers stayed on, but according to schedule, radio communication was discontinued. No one disturbed me, not a sound came from the earth. I strapped myself to the chair with special belts. I had been taught by the physicians to fall asleep at will and wake at a prescheduled time. I shut my eyes and went to sleep. The ship's radiotelemetric controls and the various systems that took care of the cosmonaut's vital functions continued their noiseless operation. I awoke because of the strange position of my body. My hands were raised and hanging in midair. I put them under the belts and looked at the diagram of a special counter that showed me the ship was in its eighth circuit. I woke up again when the ship made its tenth, and then when it made its eleventh circuit, glanced at the counter and went to sleep once more. It was fine sleeping in space, no need to turn over every once in a while because neither my hands nor legs became numb. It was like lying on a sea wave. I was scheduled to awaken at two o'clock sharp and get down to work. But I slept another 35 minutes. Down on earth they knew I was oversleeping but did not wake me. Immediately after I had gone through the morning routine, I went back to work. The ship's equipment functioned with clock-like precision. I felt rested and refreshed and all unpleasant sensations were gone. I reported this to earth. The radiogram transmitted, I went through my daily dozen. Exercise has long been a habit with me. I don't feel in form without it. Exercise in space? It would seem that physical effort is not possible under zero gravity conditions, but allowance had been made for weightlessness, and our physicians and physical training instructors had worked out a special set of exercises. One for abdominal muscles, for example, requires the cosmonaut, when he is strapped in, to try to tear his body away from the chair. There were exercises for other muscles and for the joints. The exercises activated my heart and generally invigorated me."

Analyzing Titov's Responses

Yazdovsky said these observations by Titov will require careful analysis and will serve an initial point for special investigations in this direction. Yazdovsky noted that the vertigo and discomfort experienced by Titov resembled seasickness. "These weightless unpleasant sensations of the vestibular were felt stronger and stronger, especially when the astronaut sharply turned his head or was observing swiftly moving objects. After sleep, these phenomena decreased but did not disappear before the action of overloads during the ship's recovery to earth." Titov did not use drugs to induce sleep or relieve the vertigo; Titov did not dream during his sleep in the weightless state. The professor noted that the Titov sensations may be peculiar to Titov and a scientific judgment can not be made until a series of manned experiments are performed.

Although there is some question as to the orientation of the Vostok on reentry, Yazdovsky and Titov both made it clear that acceleration and deceleration were taken "chest to back." Yazdovsky expressed concern about the deceleration force following a long period of weightlessness, and indicated that the re-entry g's should be reduced, as much as possible, to assure

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a successful flight, especially after long exposures, like a lunar mission. In the March 1961 issue of *Meditsinskiy Robotnick*, Kositskiy stated, "Important to the cosmonaut is the physiological problem of transition from the state of weightlessness to the abrupt increase in the organism's weight. Here the increase in the force of gravity will be endured with far greater difficulty than at the beginning of the flight, because the prolonged absence of weight causes a weakening in the appropriate mechanisms of body circulation control and other physiological processes. In this connection, the maximum stress following weightlessness may equal only four or five times the force of gravity (not seven or eight times as at the start of the space flight)." Yazdovsky noted that they are attempting to reduce the deceleration g's.

Low G for Re-entry

It now appears that manned space flight will require very low re-entry g's; and since this cannot be accomplished without a great expenditure of energy, the use of aerodynamic techniques offer great promise. Re-entry decelerations not to exceed 2 g's (except in an emergency) are possible to achieve from a design standpoint. The recent work of Gervais, DuPont, and Lowe on "A Practical Manned Entry System" (presented at the ARS Lifting Re-entry, Vehicles, Structures Materials, and Design Conference in April 1961) shows that re-entry can be held to a low level by the use of an aerodynamic configuration with a high L/D ratio. To satisfy the low-g re-entry, the appropriate angle of attack and lift/drag ratios have to be used. These are well within our design capability. Since these reduced-g entries are not obtainable for all entry considerations, adequate guidance must be available. We have guidance accuracies which lie within the limits of the entry corridors defined by Gervais, et al. Re-entries begun at 40,000 fps are possible without exceeding a 2-g limit, and 50,000 fps entries can be made without exceeding 4 g.

Bioinstrumentation. Bioinstrumentation on the Project Mercury MR-3 flight consisted of the measurement of the following physiological parameters: Body temperature, respiration rate and depth, and electrocardiographic measurements. NASA noted that a blood-pressure device will be incorporated in future Mercury flights. The Russians used the blood-pressure-cuff method during Titov's flight. The development by J. Waggoner and his associates at Air Research Mfg. Co. of an undirectional microphone with associated 35-cycle filtering circuits appears to be a definite advantage. However, Soviet and American scientists agree that the pressure-cuff method is not satisfactory.

Continuous blood-pressure monitoring is certainly more desirable. In a personal communication, Ben Ettelson, president of Spacelabs, Inc., stated they have recently developed a system which provides a continuous measurement of cardiovascular dynamics using pulse-wave velocity.

The velocity of propagation of the pulse wave depends upon arterial extensibility, which in turn is related to internal blood pressure. The utilization of pulse-wave velocity (PWV) for arterial blood pressure measurement establishes an indirect method for continuously monitoring cardiovascular dynamics.

Earlier investigations of the PWV measurement suggested its use as a dynamic expression of the integrative function of the entire cardiovascular system and described it as being more useful than the static measurement of the occluding cuff. This situation is somewhat analogous to the day when the principles of d.c. circuits were well understood but failed to explain the dynamics of a.c. circuitry. Although the early experiments were carefully executed, the tedious methods of data acquisition and reduction made this method fall into disuse. This instrument utilizes two readily available inputs, the cardio-electric potentials and the volume increases of a bolus of blood. The first signal is sensed with standard ECG electrodes and the "R" wave is used to trigger the timing circuit. The latter change may be detected by a capacitor pick-up, crystal microphone, or plethsmograph and terminates the time measurement. An important feature of such a system is that time is being measured and not displacement; therefore sensor placement is not critical. A known delay of approximately 20 millisec is inserted into the computer to compensate for the delay between the appearance of the "R" wave and the mechanical contraction of the heart and ejection of the blood. Extensive tests are being conducted at UCLA and Spacelabs to verify and catalog this measurement as a diagnostic tool for the physician.

In a book by L. P. Shuvatov titled "A Micro Apparatus for the Registration of Certain Physiological Functions by Radio," published in 1959, the basis for the Soviet biotelemetry system is outlined in detail. The leather helmet worn under the spacesuit helmet is, in fact, a multichannel radio transmitter. This biotelemetry system includes a transmitter and the various pick-ups needed to obtain physiological data, such as recording pulse, respiration, body temperature, mechanograms, brain biocurrents, oxyhemograms, and cardiac sounds. This system leaves the subject free to move around without the encumbrance of the wire leads. Shuvatov describes a six-channel transmitter, several pick-ups, and receiving systems in a clear and concise manner. He concludes that, "The comparatively simple transmitting systems make it possible to record fairly accurate oscillograms, both of the bioelectric potentials, of the respiratory musculature, and of such slowly varying processes as body temperature and the oxygen-saturation level of the blood, that is, processes quite different from each other both in frequency and current pattern. Experience has shown that all of the systems described ensure a uniform level of recorded signal independently of changes of distance during the experiment, this being achieved by means of the circuits that automatically control amplification and the frequency of the heterodyne oscillator in the receiver. Parameter stabilization in the transmitting systems insure stability of the transmitter frequency within the limits of ± 30 kc. The reliability of the apparatus depends upon the quality of assembly, the life of the tubes, capacitors and resistors, etc. The results of investigating various forms of microapparatus for recording physiological parameters under 'free behavior' conditions point to the possibility of widespread application of such devices in different branches of natural science."

Russian's Radio Helmet

The Soviet radio helmet transmits in the 38-40 mc frequency range, with frequency modulation of the carrier and amplitude of the subcarrier frequency. Frequency modulation on the carrier increases the range while reducing the noise level. In designing the Soviet transmitting system, the following requirements were taken into account:

1. Selection of most efficient channel and pick-up circuits combined with maximum simplicity. This also increased the reliability of the apparatus, because the fewer are the components in each channel, the less likelihood there is of stray coupling between components and circuit elements.

2. Reduction of the weight in the radio helmet by using junction-type triodes in the subcarrier AF oscillator and muscle biocurrent amplifier circuits.

3. Choice of an operating regime less sensitive to fluctuations in the power supply and temperature changes.

After a series of experiments, the

Soviets developed a radio-telemetering system operating at least at a range of several kilometers between transmitter and receiver and offering satisfactory recording of the six measuring channels. The transmitting system consists of a three-stage transmitter, five subcarrier frequency oscillators, two magnetic amplifiers, muscle biocurrent amplifiers, and pick-ups. Power is supplied to the apparatus by a filament battery and miniature batteries.

In the radio-helmet circuit there are five subcarrier AF oscillators with the following distribution: 17,200 cycles, the highest subcarrier frequency, modulated by the brain biocurrent amplifier; a 7300-cycle subcarrier modulated by the respiration pick-up; a 12,350-cycle subcarrier modulated by the pick-up for recording the oxygen-saturation level of the blood; a 730-cycle subcarrier modulated by the pulse pick-up; and a 3000-cycle subcarrier modulated by the temperature pick-up.

Audio-Spectrum Coverage

Thus, the AF spectrum extends from 730 to 17,200 cycles. The average percentage modulation of the subcarriers is 45%. The frequency deviations of the transmitter is ±50 kc. Although the six-channel transmitting system is mounted in a radio helmet, the more powerful powerpack is carried in the coat pocket. Several American companies are developing microsized transmitters and appropriate physiological sensors for biotelemetry. As an example, the work of Hughes Aircraft Co. on a 0.5-lb, 12-channel biotransmitter was displayed at the ARS Space Flight Report to the Nation. This device will accept and transmit up to 12 physiological sensors to the X-15 aircraft receiver. This type of biotelemetry system will free the pilot from the present umbilical cord. The results to date of work by Lear, Douglas Aircraft, Spacelabs, Boeing, and many others look very promising.

In the Titov flight, the following physiological parameters were measured: Respiration (rate and depth), EKG (heart rate), phonocardiography (heart sounds), temperature (several skin sensors), blood pressure (arm-cuff), and EEG. Radio-voice communications and television were also used to determine the cosmonauts psychophysiologic condition. Although the EEG measurements were just a trial on this flight, they apparently were telemetered successfully during launch, orbit, and recovery. The method of electrode attachment was not mentioned. According to *Pravda* (Sept. 8, 1961) the Vostok cabin temperature was maintained between 10 to 25 C, and water vapor at 50–70%. Before launch, there were small variations in the frequency of respiration and increase in heart rate—90-106 beats per min—and for 1 min before the start, Titov's pulse rate reached 120 beats a min. During the flight, pulse reached 118–134 beats per min, caused by a combination of noise, vibration, and acceleration. In orbit, pulse rate varied within 80 to 100 beats per min according to Titov's activity. During sleep it fell to 54–56 beats and corresponded to prelaunch figures. Yazdovsky said there were several kilometers of magnetic tape with telemetered physiological data that would take months to review and analyze.

Although Gagarin and Titov subjectively felt that the other stresses accompanying the acceleration did not decrease their tolerance, Yazdovsky remarks. "Notable is the fact that the frequency of pulse and breathing as well as other objective indexes of the condition of some physiological functions during flight considerably differed from those registered on the centrifuge."

Space Radiations. Space radiations will continue to be an unknown problem until adequate measurements have been made and the possible biological effects assessed. Efforts have been made to evaluate the magnitude of large uncertainties into the radiation data and shielding calculations. The environmental data considered have been the absolute intensities and spacial distribution of the Van Allen radiation, solar cosmic radiation, and galactic cosmic radiation and the composition, energy spectra, and time variations of these radiations. In turn, the uncertainties in the biological effectiveness of the radiations is a continuous study area. The Discoverer XVII and XVIII radiobiology experiments are only the beginning of an extensive NASA and USAF program.

To date, the Soviets have exposed and recovered many types of living organisms. As an example, on Aug. 19, 1960, the second spaceship weighing 4600 kg was launched as a prelude to Titov's flight. According to G. V. Petrovich (*Herald of the Academy of Sciences*, USSR, No. 9, 1960), Spaceship II contained two dogs (Strelka and Belka), 40 mice, two rats, several hundred insects, ground plants, algae, grains of cereal, fungi, several kinds of microbes, and other biological items. More specifically, the organisms were identified as "insects—drosophila in 15 flasks; plants—spider-worts in flowers in two flasks, Chlorella in eight ampules in a liquid nutritive medium in suspension form and in four ampules in slant agar; fungal cultures—Actinomyces in 14 ampules; seeds—corn and different varieties of wheat, peas, onions, and Nigella. The space cabin also contained small segments of preserved human and rabbit skin in two ampules; HeLa cancer cells in six ampules; and microbes—KK-12 intestinal bacilli in 11 ampules, B intestinal bacilli in six ampules, intestinal bacilli of the aerogenes type in four ampules, butyric acid fermentation bacteria in two ampules, staphylococci in two ampules, deoxynucleic acid in six ampules, T-2 bacteriophage in three ampules, and 13–21 bacteriophage in three ampules."

When asked why human cancer cells were sent into outer space, Professor Parin replied that his experiment had no direct bearing on the problem of treating cancer. The prime purpose for the investigations in Spacecraft II was to study the influences of cosmic radiation.

It must be concluded that the shielding calculations to date at best constitute rough estimates and that much additional work will have to be accomplished to clarify the biological shielding requirements. As a result of uncertainties, there will be a tendency to overshield in the early exploratory flights.

In the beginning, safety requirements must be realistic if rapid progress is to be made. After the initial exploration phases, there is every reason to believe that space transportation can become as safe as present modes of travel on earth. The development of nuclear vehicles will make it impossible to traverse great distances in space in relatively short periods of time, thereby reducing the exposure of astronauts, and eventually passengers, to the possible environmental risks of space.

For the moment, we are looking forward to next year's accomplishments and a better exchange of bioastronautic data with the Soviet scientists. ♦♦

NASA Spurs Space Research in the Midwest

NASA has founded a cooperative information-exchange and research program among the states of Arkansas, Iowa, Kansas, Nebraska, Missouri, and Oklahoma with the institution of a quarter-million-dollar yearly grant to Midwest Research Institute of Kansas City, Mo. The objectives of the program will be to increase participation of university science groups of these states in the space program and to stimulate the states' industries to make use of space technology.

Hypersonics

(CONTINUED FROM PAGE 41)

corridor depth decreases very rapidly with increasing entrance speed (for example, for a nonlifting vehicle it is reduced from about 55 mi. at satellite speed to 7 mi. at escape speed) and this in turn leads to very difficult guidance problems. However, the use of small amounts of aerodynamic lift, corresponding to L/D ratios of about 1, can through a more uniform dissipation of the kinetic energy widen the corridor by factors of as much as 3 to 5. Here again, however, a penalty is paid since lift-drag ratios greater than 1 introduce severe heating loads. Furthermore, Wong and Goodwin[2] have also shown that the use of lift results in radiation heating from the hot gas to the body which can be of the same order as the maximum convective heating and can occur at the same time. In addition they also point out that nonequilibrium boundary-layer effects become significant in the region of maximum convective heating, although this may actually turn out to be advantageous.

Clearly, one of the critical problems associated with lifting re-entry design is the achievement of L/D ratios of about 1 for the high-speed, high-altitude conditions being considered. The difficulty of developing appreciable lift on a body in a low-density flow is readily seen from the free-molecule limit. In this case, at infinite Mach number for a body which is highly cooled (a surface to stagnation temperature approaching zero), with an accommodation coefficient of unity, the theoretical lift is zero—independent of the shape. On the other hand, the drag of the body remains finite. Because of the recognition of this fact, a good deal of effort has been expended on determining not only the altitude boundaries but also the hypersonic aerodynamic characteristics for the regimes of rarefied flow, particularly in the transitional regime between continuum and free-molecule flow.

Concave-Surface Effects

Up until recently, most free-molecule aerodynamic calculations had been carried out for convex configurations. Chahine,[3] however, has considered the problem of concave surfaces with the resulting effects of molecular inter-reflections, at least for constant surface accommodation conditions. He finds that the results of these inter-reflections, when compared with the convex case, is to increase the over-all values of convective heat transfer to the surface, and, more important, to increase or *decrease* the net axial forces, depending on the concavity of the surface.

Studies into the behavior of aerodynamic characteristics in the transitional rarefied regime have generally been divided up conceptually on the basis of whether the geometry being considered is blunt (for example, a stagnation point) or slender (for example, the rarefied flow near the leading edge of a flat plate), although of course from a fundamental point of view the actual physical phenomena encountered do not differ. Some advances have been made into how and at what altitude a shock wave and continuum-type flow field develop in the nose region of blunt bodies reentering the atmosphere. The principal idea employed in the analyses is that, although the free stream may be rarefied, the gas near the surface of the body has a continuum-like behavior due to the strong compression at hypersonic speeds.

By extrapolating continuum concepts to lower densities, and free-molecule and near-free-molecule kinetic concepts to higher densities, the writer has attempted[4] to delineate the various types of flow regimes encountered by a re-entering vehicle down to low-altitude conditions. The results of this study suggest that for a cooled blunt body the appearance of a definable shock wave occurs very rapidly in terms of density change near the beginning of the transitional-layer regime (about 75-mi. altitude) and that this regime itself, where the flow can be considered neither continuum nor highly rarefied, has a depth of only about 10 mi. Rott and Whittenbury[5] have proposed a flow model for calculating the transitional regime based on a two-fluid concept of an incident molecular beam mixing with a gas-like flow near the surface. The results they have obtained for sphere drag prove to be in qualitative agreement with experimental data. In this regard, we may mention that some of the most complete high-speed-sphere drag data in the transitional regime has recently been published by Wegener and Ashkenas.[6] The data show that at a Mach number of about 4 the sphere drag coefficient increases monotonically from a value of 1.19 at a free-stream Reynolds number of 1000 to 1.73 at a Reynolds number of 50 ($C_D = 2$ for free-molecule flow with unit accommodation coefficient).

Various artifices have also been employed to extend the results of continuum theory through the transitional regime to free-molecule conditions. Perhaps the most interesting of such calculations for hypersonic flow has been that of Cheng,[7] which was carried out for the stagnation region of blunt bodies. In Cheng's analysis, he modifies the Rankine-Hugoniot shock conditions to take into account the effects of shear and heat conduction behind the shock. Using the new shock conditions as outer boundary conditions in a thin-shock-layer viscous analysis, he has been able to show that his calculated shear and heat-transfer results can be extended to encompass the whole regime between boundary-layer and free-molecule flow. Interestingly and perhaps surprisingly, his results do in fact go over smoothly to the free-molecule value for an accommodation coefficient of unity. The question of the validity of using the continuum equations at such low densities is, however, still unanswered.

Blunt Bodies Studied

Somewhat less ambitious attempts to extend continuum viscous hypersonic aerodynamic characteristics on blunt bodies to lower densities have centered around mathematically valid second-order modifications of boundary-layer theory. These modifications result from displacement effects, the effect of external vorticity on the viscous-flow, curvature, and slip effects. If only the Reynolds number is considered as a parameter, they can all be said to be of the order of the inverse square root of the Reynolds number. In fact the major results of these calculations (for example, Van Dyke[8] and Maslen[9] have been to show that for the stagnation region of blunt bodies the relative increase in the shear and heat transfer over the boundary-layer value resulting from the sum of these second-order effects is roughly equal to one-half the inverse square root of the Reynolds number. In this case, the Reynolds number is defined as the product of the free-stream mass flow times the body radius divided by the viscosity based on stagnation conditions. Germain and Guiraud[10] have also studied the effects (which are inversely proportional to the Reynolds number itself) of the thickening of a nearly normal shock wave in a low-density flow.

With slender configurations somewhat less work has been done on the calculation of low-density characteristics outside of the range where results can be obtained by modification of boundary-layer theory. This is principally because of the increased mathematical difficulty. However, Charwat,[11] by the use of simplified kinetic scattering models has been able to develop a near free-molecule analysis which predicts the manner in which the pressure rises from its free-molecule value at the leading edge of a flat plate to a peak-pressure value somewhat downstream. This peak

pressure was also obtained by Oguchi[12] in a completely different manner from a viscous shock-layer continuum analysis which starts from downstream rather than at the leading edge. The theoretical results of both analyses are in reasonable agreement with the experimental pressure-distribution data reported by Nagamatsu, et al.[13] These data have recently been extended to encompass the corresponding heat-transfer problem.[14]

Outside of the rarefied flow regime, the aerodynamic lift (and moment) is determined primarily by the pressure distribution, which in a hypersonic flow is affected by viscosity through the thickening of the boundary layer, which in turn alters the pressure. This effect is most important on slender configurations. As for the drag on slender bodies, it is composed principally of the drag due to viscous shear, the pressure-distribution drag, and the drag of the blunt leading edge if the body is not ideally sharp (which is almost always the case). Recent calculations in the high-density range (both viscous and inviscid) have concerned themselves with the effects just mentioned, with emphasis on lifting configurations and slightly blunted slender bodies, because of their already mentioned practical value in connection with the re-entry problem.

Tsien-Hayes Work Extended

In inviscid hypersonic flow theory, an important extension of the Tsien-Hayes equivalence principle to slender bodies at large angles of attack was made by Sychev.[15] He showed that for such bodies the displacement of the gas takes place in planes transverse to the axis of the body and the flow viewed in any transverse plane is independent of the flow in any other plane. From this result, a hypersonic similitude can be developed which permits the determination of the lifting aerodynamic characteristics on similar bodies at hypersonic speeds once they have been found experimentally or theoretically on one configuration.

Inviscid Newtonian flow theory has also been extended to slender wings at large angles of attack[16] where the flow is essentially in the spanwise direction, as well as to nonaxisymmetric conical configurations.[17] In such three-dimensional flows, the pressure interaction due to the interaction of a thick viscous boundary layer with the inviscid field can be of considerable importance due to the low density in the boundary layer, which makes it susceptible to spanwise pressure gradients. Dewey[18] has concerned himself with this viscous pressure interaction on yawed lifting surfaces, and has carried out his calculations by assuming a locally similar character for the three-dimensional boundary layer. One of the interesting results he finds is that the heat-transfer rate on such wings does not change appreciably as the yaw angle increases. The theoretical distributions of both pressure and heat transfer found from these analyses are in agreement with the high Mach number experimental data of Bertram and Henderson[19] obtained on a variety of three-dimensional lifting configurations.

The particular feature peculiar to the slightly blunted slender body is the high entropy layer near the surface resulting from the flow that passes through the strong part of the detached shock wave at the nose. This layer of hot, low-density gas behaves very much like a boundary layer, and the displacement effect of this entropy layer can, like the boundary layer, have a marked effect on the pressure distribution and hence the force characteristics. Sychev[20] and others[21–23] have recently studied this problem analytically from the boundary-layer point of view with some success. Vaglio-Laurin and Trella[24] have also carried out a correlation of a large number of numerical solutions on slightly blunted slender bodies, and these results along with the analytic results have shown that blast-wave theory, which does not account for the entropy layer effect, can lead to serious errors in computing the flow field. Cheng, et al.[22] in a rather comprehensive paper have also studied the viscous displacement effect both theoretically and experimentally on such bodies. By using a model of an inner laminar boundary layer, an outer detached shock layer, and an entropy layer intermediate between these two, these authors have arrived at a combined similitude rule which appears to be borne out by experiment. It might be noted that angle-of-attack effects were also considered. A combined treatment of the viscous and entropy layer has also been given by Murzinov.[25]

As previously pointed out, the problem of heat transfer in re-entry design, particularly at supercircular speeds, is a crucial one. Under such conditions radiative heat transfer from the gas to the body may be dominant, and nonequilibrium chemical effects will have to be considered when calculating not only the convective but also the radiative heating. Recently calculations have been carried out for the stagnation region of a blunt body on the effect of equilibrium gas radiation both from the shock layer and boundary layer. Kivel[26] has shown that the equilibrium inviscid shock-layer radiation heating can be of considerable importance for velocities greater than 30,000 fps and at altitudes less than about 25 mi. At higher altitudes (greater than 30 to 40 mi.) the most dominant heat source may turn out to be nonequilibrium radiation. This is associated with the fact that the gas itself may not reach chemical equilibrium in the nose region of the body, with the result that high overshoot nonequilibrium temperatures can appear which lead to a considerably increased total radiation intensity.[27] Correspondingly complete radiation calculations for the stagnation-point boundary layer have not as yet been made. However, Howe[28] has examined the equilibrium radiation problem taking into account emission but neglecting absorption. As might be expected for the thin boundary layer, his results show the effect to be small. An approximate treatment of both the absorption and re-emission problem has been given by Rumynskii,[29] although he presents no numerical calculations.

Surface Radiation Studied

The problem of surface radiation, which has been extensively treated for continuum flow, has been considered by Abarbanel[30] for free-molecule conditions. One significant result he finds is that the radiation problem admits of similarity solutions for various geometries.

Recently Chung[31] has looked into the problem of nonequilibrium boundary-layer heat transfer at the nose of a blunt body for altitudes from 200,000 to 300,000 ft and speeds near satellite speed. His calculations indicate that the controlling chemical reaction for heat transfer at the higher altitudes is the dissociative shock-layer reaction, while at lower altitudes it is the boundary-layer recombination. One very interesting conclusion is that the nonequilibrium chemical reaction can significantly reduce the heat transfer to noncatalytic walls at altitudes of the order of 40 mi. This follows from the fact that most ablating materials, particularly low-temperature ablators, are effective in reducing the number of dissociated atoms which can reach the wall, and in this way they prevent the recombination energy from being delivered to the wall. In a beautiful experimental paper by Cutting, et al.,[32] the authors show that, for a frozen dissociated boundary layer, the total heat transfer to a fine wire could be reduced by as much as a factor of 3 by coating the wire with iodine so as to provide a noncatalytic surface.

An examination of the effect of electronic heat conduction in the bound-

ary layer has been carried out by Adams,[33] who has found that in the speed range of 25,000 to 45,000 fps the electronic effects lead to no more than a 30% increase in convective heating. However, this writer feels these results may be optimistic and that the problem requires still further investigation, since the calculations were made for a frozen boundary layer and the equilibrium case may tend to produce higher heat rates.

Although many analyses have been made on the advantages of light-gas injection at a body surface in reducing heat transfer, it is only very recently that Baron[34] has dispelled the myth of the tremendous reductions to be gained by this method. In fact, in his paper, which presents both theoretical and experimental results, he has shown that the injection of low-density fluids such as helium *do not* lead to the marked reduction in heat transfer (when compared say with the injection of air) which had previously been expected. He points out that this is because of the pronounced thermal diffusion present in light-gas injection, which tends to markedly reduce the favorable insulating effect of a light gas.

Many studies, too numerous to mention, of both a theoretical and experimental nature have appeared within the past year on the performance of ablating materials as heat protection for re-entry vehicles. A good number of these have been experimental measurements on ablation in turbulent flow (see, for example, reference 35). In the figure accompanying this article, we have shown a photograph of the General Electric a.c. arc facility used for turbulent ablation studies on large scale models.[36] This facility is similar to others now in use throughout the country. Results of tests such as those referred to have shown that among promising materials are low-temperature subliming ablators, such as teflon, phenolic materials, and pyrolitic graphite. A discussion of these various materials is beyond the scope of this review.

Ionized-Trial Study

The problem of theoretically determining possible observable phenomena such as thermal radiation and reflection of electromagnetic waves on and about re-entering hypersonic vehicles has centered to a large extent around the study of the ionized trail left behind the vehicle in the atmosphere. Feldman[37] has pointed out that the times required for ionization and dissociation (and the reverse recombination processes) to go to completion when compared to the flow times of a gas particle are important in determining the observable effects of hypersonic trails. In consequence of this, a great deal of effort has been expended on the calculation of nonequilibrium gas flows, both viscous and inviscid, in an effort to specify, among other things, the electron-density profiles in the flow. Two summary papers on nonequilibrium flow calculations have appeared in 1961.[38-39] One conclusion that can be drawn from an examination of the work in this field[38] is that, because the chemistry is essentially a molecular process, while the fluid flow is a continuum one, it is difficult to find flow models which fit both situations. The result is that emphasis must be placed on brute-force numerical calculations (sometimes involving the chemical kinetics of as many as 20 to 30 chemical reactions). A good example of this is to be found in the paper of Vaglio-Laurin and Bloom[40] where the authors have, by essentially numerical means, made an attempt to calculate and correlate the observables in complete inviscid flows, at least in the equilibrium and frozen-flow limits.

To calculate the required flow fields, a knowledge of the basic kinetic properties is necessary. An excellent summary of some of the basic data on the chemical kinetics of high-temperature air may be found in the paper of Wray,[41] while a good summary discussion of the basic radiating properties of high-temperature air has been given in the recent paper of Treanor.[42]

With regard to the wake problem, studies have been made of the equilibrium laminar wake,[37,42] which have shown that the cooling of the wake behind the body is due primarily to heat conduction. This is, of course, a relatively slow process, with the result that calculated electron trails behind blunt objects may extend quite far behind the body. For example, for a 1-ft sphere in the altitude range between 60,000 and 100,000 ft, the ionized wake, based on reasonable minimum-ionization levels, may extend up to 2 mi. behind the body. Thus far, the calculations made have only been for equilibrium flows, and much remains to be done in the nonequilibrium case. Because of the many unknowns involved in calculating a turbulent wake, the corresponding turbulent-trail problem, even in the equilibrium case, has not been treated extensively. Lees and Hromas[43] have made an attempt to study the problem by using a local similarity assumption in the calculation of the turbulent spreading. The results they obtain for the growth of the turbulent wake behind a sphere, which at large distances goes like the cube root of the distance, appear to be in good agreement not only qualitatively but also quantitatively with the ballistic-range measurements of Slattery and Clay.[44]

Unfortunately, all of these wake calculations, both laminar and turbulent, require certain assumptions regarding the behavior ahead of the recompression shock of the near wake immediately behind the body. This near wake is an old problem in fluid mechanics, and still an unsolved one. An attempt to extend Chapman's now classical separated-flow analysis to calculate the near wake in axisymmetric supersonic flow at the base of a body has been made by Minyatov.[45] Although one can determine the base pressure from these calculations, the treatment itself involves some very basic assumptions which are open to question. Apart from neglecting the reverse flow in the dead-water region, there is an assumption regarding the wake-neck diameter and the assumption that Mangler's transformation can be applied to calculate the boundary-layer-like mixing region. Clearly, a great deal more work remains to be done in this area.

Radar Probing of Vehicles

A review of some of the actual experimental methods of obtaining plasma properties on re-entering hypersonic vehicles from radar-return data has been given in the paper of Pippert and Edelberg.[46] These authors have studied the radar reflection and transmission through the wake plasma column in an effort to deduce the properties of the vehicle itself. However, it is evident from this paper that the interpretation of re-entry observables will involve a good deal better understanding of both the fluid-mechanical and electromagnetic scaling laws and of the characteristics of high-temperature flows than exists at present.

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Peres Heads IAF

(CONTINUED FROM PAGE 59)

on the Russian Venus experiment ran straight up against reports from the MIT and JPL groups on their work, presented by Pettingill and Goldstien, respectively. The American and Russian findings roughly agree on the Astronomical Unit (USSR—149,599,500 km; JPL—149,598,820 km; and MIT—149,597,850 km), the Russians having revised their first reported figure, but still distinctly disagree over the nature of return radar signals, on which turn interpretation of Venus rotation. After a lunch together, Kotelnikov, Pettingill, and Goldstien came back looking pretty grim and had no joint opinion to offer about their results.

The nub of Kotelnikov's argument about Venus rotation appears in this sentence from his paper: "If one supposes that the whole viewable disk of the planet reflected and that its axis was perpendicular to the direction of the (incident) radiation, then this velocity (the approximately plus or minus 40 meters per sec of frequency shift recorded by the Russians) corresponds to a rotation period of approximately 11 days. If the rotation axis was 60 deg . . . then the period of rotation would be about 9–10 days."

Kotelnikov argues that the American experiments make the center of the Venusian disk the source of re-radiated energy, and then of course there appears no frequency shift in the U.S. returns, and consequently no evidence of rotation. The MIT and JPL experimenters, and a number of people in the audience, it was clear, suspect an internal error in the Russian instrumentation.

So this question of the planet's rotation, and the several theories on the nature of the planet strongly affected by it, remains open, probably until the first successful Venus probe. Moreover, the value for the A.U. is not completely settled.

Reports on Jupiter and Mercury, and an outline of the potential of the NRRS 600-ft radio telescope, plus many glancing remarks from the audience, make it clear that the field of planetary studies is just beginning to open up, and that Jupiter, in particular, will receive growing attention from both the astronomers and spacecraft designers.

The next big meeting on planetary results will come in the first week of July of next year at Liege, Belgium, and will be preceded the last week in June by a symposium on the moon at the Univ. of Manchester in England.

The human-factors sessions provided one of the big topics of corridor conversation—Titov's sickness throughout most of his flight, as described by Col. Yazdovsky. Although concerned with this event, the Russians appear

well aware of the difficulty of interpreting Titov's reactions to weightlessness. At a showing of a popularized film account of Gagarin's nonorbital exploits on Friday evening, the last day of the meeting, Col. Yazdovsky specifically pointed out that individuals will likely differ considerably in response to weightlessness, and that to study this problem one should make a series of flights with different astronauts.

Although speculating in their paper on possible means to cope with motion sickness, the Russians conclude with the remark, "The decisive word will belong to the experiment." A film on Titov's flight was to have been shown at the Congress, according to Col. Yazdovsky, but was reported held up in New York Customs. This picture was said to show some of the preparations for longer flights than Titov's.

In private conversations, the Russians showed interest in measuring arterial pulse-wave velocity. Air Force work on this was mentioned by AF Capt. George Potor in a brief paper given at the ARS Conference on the Anatomy of Manned Space Operations in October 1960. The Air Force did not push study of the technique, but one company believes it has a good instrument for this purpose. Methods of recording blood pressure directly have not been proven very satisfactory for space operations.

The human factors and bioastronautics clan continued their grappling with the tough problem of radiation tolerance, introduced discussion of electromagnetic shielding against radiation on a more serious level, owing to the advent of the superconducting magnet, and showed their concern over possible contamination of extraterrestrial bodies that will be targets for space probes and landers. George Hobby of JPL, answering questions from the floor after reviewing proposed schemes for biological sampling and inspection, stated that there has been an effort to get together with the Russians and formulate agreements on sterilization and experimental procedures, and that U.S. representatives hope to solve problems in this area before the first Mars lander. Hobby also remarked that the field of exobiology is wide open.

Mrs. Herbert Friedman, right background (obscure in the photo as she was not at the meeting), and Mrs. H. Kafafian in the foreground, together with Mrs. Samuel Herrick, did yeoman service at the Congress organizing functions and doing services for attendees and their wives.

In a session the last day of the Congress, Iteba of Japan, Dryden of the U.S., Pardoe of Great Britain, and Grandpierre of France reported on results and plans in international astronautics. Professor Sedov, representing the USSR, was scratched at his request from the session. Dr. Dryden mentioned again, as he had at the opening ceremonies, that the U.S. has begun a program of international scholarships in astronautics, with 23 initial students. There was otherwise little new revealed. It has become clear that the Japanese will push their Kappa 9 development, hoping eventually to compete with the U.S. in supplying Scout-class boosters to foreign countries. They reportedly have contracts with Yugoslavia and Argentia to supply some dozen Kappas for experimentation.

On the European scene, the space-paper dust has not really settled. The announcements early in summer of agreement among the major European countries on a joint space program would appear premature. On the other hand, vehicle and facility papers by British representatives at the Congress—for instance, the design study of a dual-thrust lox-hydrogen third stage for Blue Streak presented by Anthony Mottram, chief research engineer for Bristol Siddeley Engines—showed sophistication and pointedness. There is evidence that the Europeans do not intend to be put in the position of accepting worldwide satellite communications just on any terms. Moreover, the really enthusiastic European delegates talked about fielding a joint space program comparable to the present U.S. one before the end of the decade. The European economy will certainly by then support a broad space program. ♦♦

Solid Propellant Rockets

(CONTINUED FROM PAGE 50)

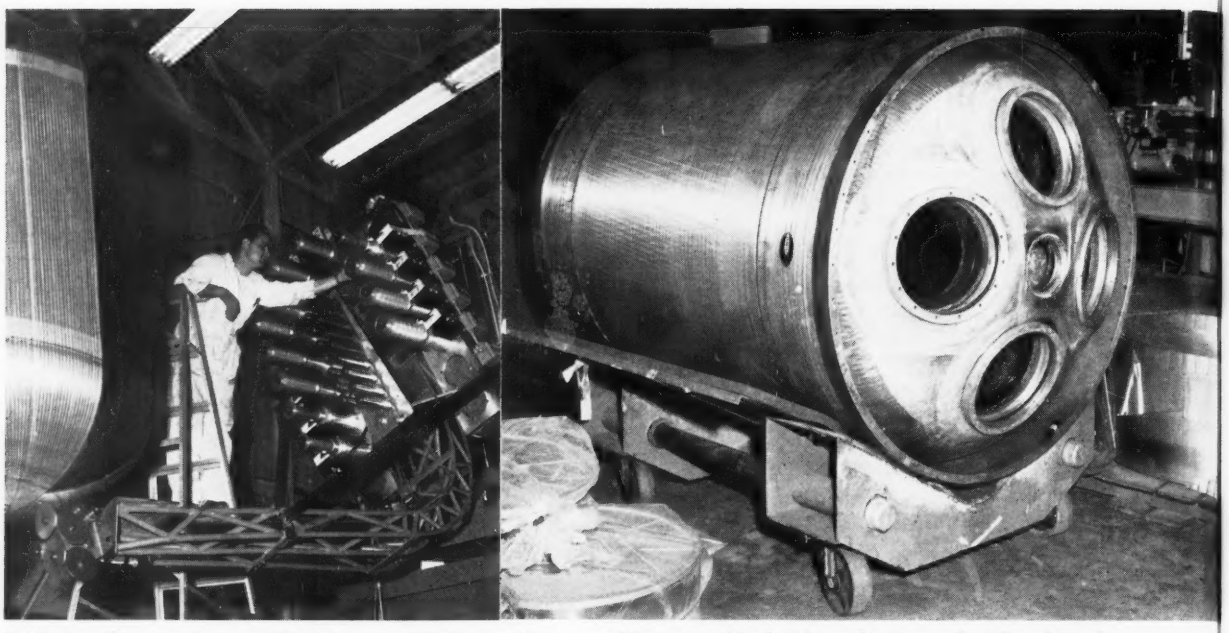
Shortly after allocation of the funds, the Department of Defense and NASA wisely decided that some very careful planning should be done so that money spent now for development of large rocket engines, either liquid or solid, would be used to develop a powerplant which would be of maximum usefulness over the next 10 years. A joint DOD-NASA Committee, co-chaired by Nicholas Golovin of NASA and Lawrence Kavanau of DOD, was appointed to make a comprehensive study for 90 days to determine the optimum sizes and types of boosters which should be developed. The Committee is composed of representatives from DOD, NASA Headquarters, NASA Marshall Space Flight Center, Navy Special Projects Office, Air Force Headquarters, Air Force Systems Command, and Aerospace Corp. The work of the committee was scheduled to be completed by November 3. By the end of January 1962, it is anticipated that major development on possibly two different sizes of big solid booster engines will be underway.

Meanwhile, both the AF and NASA have sponsored programs to demonstrate the feasibility of building very large solid rocket motors based on the segmentation principle. This is the idea of building very large rocket motor cases in longitudinal segments, loading each segment with propellant, and then transporting the loaded segments to the launch site for assembly. The results of these programs have made headlines in newspapers and magazines throughout the country. The photo on page 51 shows a 100-in.-diam segmented flight-weight motor weighing about 80 tons which was successfully static-tested by Aerojet-General in August 1961 for the AF. The motor developed a maximum of about 500,000-lb thrust and had a web burning time of approximately 65 sec.

Big UTC Motor Fired

In August, working under NASA contract, United Technology Corp. static-fired a flight-weight segmented motor slightly tapered throughout its length and 96 in. in diam at its largest section. The motor weighed approximately 75,000 lb and developed a maximum thrust of about 250,000 lb for a duration slightly in excess of 80 sec. The motor is shown on page 127.

In another AF program, Lockheed Propulsion Co. (formerly Grand Central Rocket Co.) successfully static-fired a 36-in.-diam scale version of a segmented big-booster engine in July and demonstrated precise control of



Solid-propellant rocketry added to its arsenal of techniques this year with fruition of over a decade of work on plastic-reinforced filament-wound pressure cases, particularly in large sizes. The photo at left shows a set-up for winding glass filaments to form a Polaris second-stage motor case. The photo to the right shows such a case for the Polaris A-3 second stage at the completion of the curing cycle.

the jet direction by injecting a reactive fluid at selected points in the nozzle divergent section.

Another significant milestone was also achieved at Lockheed Propulsion in October; a 36-in.-diam motor containing more than 6700 lb of propellant was conditioned at −64 F for nine days and then successfully test-fired at −50 F. The test was performed to demonstrate the physical properties of the propellant, to test the adequacy of the propellant-liner system, and to verify a theory for determining the structural integrity of a solid-propellant grain. The conditions of the test were carefully selected to present a propellant and propellant-liner stress condition as rigorous as any which might be encountered by a big-booster grain segment. The low temperature and a four-point-star perforation were used in the 36-in.-diam motor to simulate stress conditions characteristic of a big-booster motor with much greater web thickness, a circular perforation, and much smaller temperature variation.

An agreement has been negotiated between NASA and the AF in which the AF has assumed the responsibility for developing the large solid engines which might be used as boosters for NASA's space launch vehicles. In order to start this program as rapidly as possible, NASA has transferred $15 million to the AF Space Systems Div. (Col. Langdon Ayres) to be used for large-solid-engine component development. This program will proceed while the major development programs for the big engines await decisions concerning final specifications. This program really marks the beginning of the long-awaited dream of many in the solid-rocket industry who have advocated big solid boosters for several years.

R&D Paying Off

In addition to the success scored in advancing the acceptance of large solid engines for use with space launch vehicles, the solid-rocket industry made many important technological advances during 1961. These advances in component and motor design and performance were made possible by research and development conducted, in some cases, over a period of several years. For the state of the art of solids to continue to advance, year by year, it is necessary that a broad base of both fundamental and applied research be maintained on which growth in future years can be based.

An example of development in which significant progress has been made is the work on reinforced-plastic cases sponsored by the Navy Bureau of Weapons Special Projects Office for the Polaris project. Stated more precisely, one would have to say that 1961 saw the fruition of research and development work in reinforced-plastic chambers which was started as far back as 1947, received renewed emphasis in 1956, and has been pushed very hard since 1958. The photo at top left shows a set-up for winding glass filaments to form a Polaris second-stage case. The photo at top right shows a glass-reinforced-plastic Polaris A-3 second-stage motor case at the completion of the cure cycle. Note that aluminum skirts for attachment of the motor to the remainder of the missile are wound integrally with the case structure. In 1961, 10 Polaris A-2 flight tests have been made with plastic second-stage cases. No failures have occurred which are in any way attributable to the plastic case material.

Current technology with reinforced plastics is producing cases with strength/density ratios of over a million inches. That is equivalent to steel heat-treated to a stress level of 283,000 psi. Needless to say, steel fabricators are not standing idly by while these advances are being made with reinforced plastics. Processes are being developed which show promise of significantly bettering even this value as a working stress-level. The titanium industry is also hard at work improving the physical properties of its products, learning improved fabrication techniques, and seeking to lower production costs.

Development of improved nozzles has been given priority emphasis. All

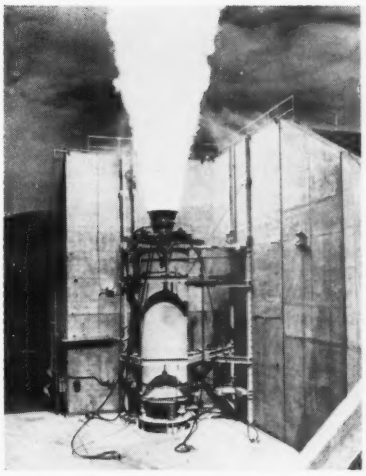
of the government agencies which have major missile responsibilities have sponsored rocket-nozzle-improvement programs. The state of the art in 1961 recognizes three distinct classes of materials and fabrication techniques which are currently being used for solid-propellant-motor nozzles.

1. For those applications where little or no throat erosion can be tolerated, tungsten has emerged as the primary candidate.

2. In those cases where small amounts of erosion can be tolerated, nonmetallic refractory materials such as pyrographite alloys are coming to be used to a greater degree. The addition of up to 2% boron to pyrographite has been found to improve its thermal anisotropy and its mechanical strength.

3. Where nozzle throat erosion is unimportant, or where the rate of such erosion can be predicted and its effect compensated for in the grain design, edge-grain carbon or graphite tape is being more widely used. Upstream and downstream of the throat section, edge-grain silica tape has proved to be reasonably inexpensive and satisfactory.

Another area in which rather significant advances have been made in the state of the art of solid rocketry is that of thrust-vector control (TVC). Use of a secondary fluid as an injectant in the nozzle divergent section to divert the main rocket exhaust stream from its normally straight-aft direction has received much attention. The result of one test of a reactive fluid in connection with a subscale version of a big booster motor was mentioned earlier. Many other agencies have performed analytical studies and small-scale experimental work with both reactive and nonreactive fluids during the past three years.



This United Technology Corp. segmented solid rocket, 96 in. in diam, developed 250,000-lb thrust in a long-duration static firing.

Nonreactive fluids which have received most attention include several Freon compounds and water. Typical reactive fluids include nitrogen tetroxide, hydrogen peroxide, and hydrazine. The injection of relatively high-temperature gas from a separate gas generator has also been investigated and is found to be quite promising for certain applications. As yet, the industry is still looking rather wistfully for a sound method of bleeding gas directly from the main motor combustion chamber, passing it through a control valve, and injecting it, as needed, into the nozzle's divergent section for TVC. The problem, of course, is being able to control the flow of 5500 F gas for durations of 100 sec or more. No satisfactory solution exists at the present time.

Broad Advances Made

In summary, progress has been made in nearly all areas of solid rocketry, starting with research and extending all the way through the development cycle of components as well as motors. The completely successful test of Minuteman No. 1 on February 1 of this year offers clear evidence of a capability for achievement with solid motors that is unmatched with any other missile propulsion system. Without question, however, insofar as the solid-rocket industry is concerned, the most pregnant of all the events of 1961 was the decision on the part of the government to proceed with development of big solids for space launch vehicles. The course of events stemming from that decision will reshape the industry in the next five years.

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Nuclear Propulsion

(CONTINUED FROM PAGE 45)

NASA-AEC Space Nuclear Propulsion Office (SNPO) was created in 1959 with authority for direction of the nuclear-rocket program. SNPO has increased its staff and efforts during the year just ended. A report on the operations of this office is given here by its director, Harold B. Finger. In addition, in anticipation of the eventual application of Nerva to a vehicle system, a Nuclear Vehicle Projects Office has been established at the NASA Marshall Space Flight Center under the direction of AF Col. Scott Fellows.

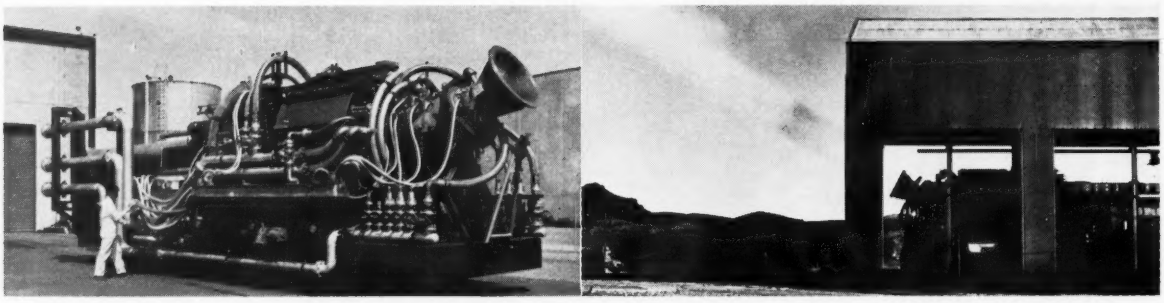
Activity at the Los Alamos Scientific Laboratory centered around preparations for the Kiwi-B series of reactor tests, scheduled to be started this month at the Nevada Test Site. The Kiwi-B reactors represent an advance over the Kiwi-A series in many respects, and will be the first rocket-reactor experiments to use liquid hydrogen as the propellant supply. Gaseous hydrogen has been used in all previous tests. Further work has been done in mission analyses and vehicle-systems studies, leading to a clearer definition of the mission areas for which nuclear rocket engines of various types find optimal application. Comparison of various chemical, hybrid nuclear-chemical, and nuclear rockets for the manned lunar mission showed the advantages of nuclear stages clearly (for example, reduced size, greatly reduced booster thrust, fewer stages, etc.). From the technical standpoint, successful completion of the Kiwi-B series of reactor tests should provide enormous incentive for the incorporation of nuclear rocket propulsion in the national lunar program.

The NASA Lewis Research Center remained active in work important to nuclear propulsion systems, with expanded studies in the missions and vehicles field, and continued experimental programs in basic areas of heat-power engineering and fluid dynamics. A brief summary of this activity is given here by Frank Rom of NASA-Lewis.

In the ramjet (Pluto) program, striking advances were registered with the completion of the first four experimental reactor test programs, carried out at the Nevada Test Site by and under the direction of the Livermore branch of the Lawrence Radiation Laboratory. Photos on page 128 show the reactor tested in the first series, Tory II-A-1, as it appeared at Livermore on its test bed and in its test installation at NTS. Unclassified details of these tests and a brief survey of the problems of nuclear-ramjet development are given here by T. C. Merkle, associate director of the Livermore Laboratory.

Industrial participation in the overall nuclear-ramjet program includes USAF contracted work by Chance-Vought Corp. on mission analysis and on aero- and thermodynamic prob-

Photos courtesy of Lawrence Radiation Laboratory, Livermore



Left, the Tory II-A test vehicle as assembled at UCRL, Livermore. The reactor core is located in the central cylindrical section of the test assembly. Right, the Tory II-A test vehicle at NTS bunker during cold blowdown test without reactor core in place (December 1960).

lems of the Slam (Supersonic Low-Altitude Missile) system; work by Marquardt Aircraft on nuclear-ramjet engine design and non-nuclear component development work; and activity in direct support of the Livermore laboratory by the Bendix Corp., engaged in development of reactor controls, by ACF Industries in the fabrication of reactor parts, by Coors Porcelain Co. manufacturer of reactor fuel elements, and by Brush Beryllium. While the presently conceived application of the Pluto engine is to an unmanned military mission, it is obvious that the high-temperature reactor technology developed in the course of this program may be useful in other propulsion and power applications.

As the year ends, we look back with gratification at the continued technical success and the expansion of effort and funding in nuclear propulsion—not pleasure at the bare fact of growth, but rather at this expression of increasing recognition of the superior performance capabilities of nuclear propulsion systems, especially for the forthcoming great adventure of manned space flight. We enter on the new year with high hopes and great expectations.

SNPO AND THE ROVER PROGRAM

By H. B. Finger

A year ago, the objective of the nuclear rocket propulsion program was to demonstrate feasibility of nuclear reactors for rockets; just completed and under evaluation was the third and last of the Kiwi-A series of reactors. The present objective of the program is to develop nuclear rocket engines for flight testing by 1966, with eventual development to provide nuclear rocket engines qualified for operational use as upper stages on advanced launch vehicles.

Major activity during the past year has been preparation for the full (Kiwi-B) series of tests which will evaluate the performance of several reactor designs. These preparations included work on a number of specific problems brought out by the A-series tests; results of this work are incorporated in the B-series reactors. Liquid hydrogen will be used as coolant-propellant for the first time during this series. Development of support hardware such as pumps and nozzles for the planned reactor test program has had to keep pace with the reactor development.

The significance of the forthcoming test series has been reflected in the public statements of both President John F. Kennedy, who stated that nuclear rockets provide the capability for missions to the ends of the solar system, and James E. Webb, NASA administrator, who stated to the Joint Committee on Atomic Energy that NASA's planned launch vehicles will be mechanically adaptable to nuclear-engine upper stages and that a contractor for the nuclear flight test system will be selected shortly after the first of next year.

In July 1961, the SNPO executed a six-month contract with Aerojet-General calling for preliminary design of a nuclear engine (Nerva) and development of a program plan leading to in-flight test, as well as other important tasks. It is anticipated that a contract for development of the Nerva engine will be executed upon satisfactory completion of the preliminary effort.

Work on nuclear-rocket test facilities during the past year included an extensive study of the over-all requirements of a National Nuclear Rocket Development Center. This study considered the methods by which the most efficient long-term use of these facilities could be made, and took into account labor forces, logistics, and services as well as the facilities required, the most economical facility layout, and the effect of radiation environments on all these. This study provides a useful guide for facility-construction policies. At the Nevada Test Site, an existing reactor test stand has been modified for liquid-hydrogen operation, an addition was made to the existing Maintenance-Assembly-Disassembly Building, and construction is nearing completion on a second reactor test complex. Work began on Downfiring Engine Test Stands and an Engine-Maintenance-Assembly-and-Disassembly Building.

A preliminary study of nuclear-engine flight test methods was completed early this year by four contractors. These studies uniformly recommended that the first nuclear-engine flight test be a ballistic-trajectory flight on a Saturn S-1 launch vehicle to a predetermined impact point in the ocean. The contractors are now engaged in a continuation of their studies to recommend the exact vehicle environment desired during flight test, the facilities and ground-handling procedures to be used, and a refined vehicle design.

In summary, the Kiwi-A tests completed last year were sufficiently successful to warrant stepping up the pace of the Nuclear Rocket Propulsion Program. A program leading to flight test of a nuclear engine has been planned, and a good start made on the ground work for an accelerated testing program. Sucessful completion of the next reactor test series should result in serious consideration of the use of nuclear upper stages for the manned lunar mission.

RESEARCH AT NASA-LEWIS

By Frank Rom

In the past year, several studies have been made at NASA Lewis Research Center on missions which may be accomplished with nuclear rockets.

These included manned interplanetary missions, manned lunar missions, and scientific space-probe missions.

Manned Missions Studied

The manned interplanetary studies, which included estimates of shielding required for solar radiations, indicated that seven man fast Mars and Venus landing missions could be accomplished with orbitally launched nuclear-rocket-powered spacecraft weighing of the order of 1-million lb. Round trips including a 40-day stay at the destination planet could be accomplished in about 400 days, which is about half the time required for a minimum-energy trip. The best chemically rocket powered spacecraft would probably weigh more than 10 times as much as the nuclear system required for these missions.

Studies of manned lunar missions using nuclear-powered upper stages on chemical boosters revealed that the thrust of the chemically powered launch vehicle could be reduced by a factor of 2 or 3 from that needed for all-chemical propulsion. Results of these studies were in good agreement with those made elsewhere (for example, Los Alamos and Marshall Space Flight Center). Following such a course would provide another string to the lunar-program bow, in addition to present effort on chemical rocket "super-boosters" and exploitation of orbital-rendezvous techniques.

Studies of high-energy scientific space-probe missions indicate that nuclear rockets may perform many missions which cannot be done at all with the best multistage chemical systems. For such application, the utility of lightweight nuclear-rocket powerplants of relatively small power output, such as may be attainable with fast reactors or thermal reactors using hydrogeneous moderators, was made apparent. Regardless of the number or type (nuclear or chemical) of stages which are used previous to the last stage, it was found that it always pays to use a lightweight nuclear final stage to achieve the substantial extra velocity increments required for difficult probe missions.

In addition to mission analysis, considerable progress has been made on experimental investigation of a number of fields important to advanced nuclear-propulsion systems. Experimental studies have been made of heat transfer from hot walls to hydrogen with dissociating boundary layers, and to hydrogen at near-cryogenic temperatures, in order to determine correlations of use in these two extreme regimes of interest in nuclear-rocket reactors. Analytical work on hydrogen-cooled and heated nozzles was also undertaken with the aim of finding optimum techniques for the design of rocket-engine nozzles for use with this peculiar fluid. Design criteria so derived have been checked by experimental work. In the turbopump field, experimental study has been continued of the problems of pumping cryogenic hydrogen and of hydrogen-gas-driven turbines. This work will provide a basic understanding of problems and processes encountered in hydrogen turbopump systems as well as a fund of information and data directly useful for design. Fluid-dynamic work in progress during the year included experimental study of flow stability for two-phase and supercritical flow of cryogenic fluids in multiple parallel passages, and air-bromine studies of phenomena in flow of coaxial gas streams.

Anticipating the future, activity at the NASA Lewis Research Center, pioneer in aircraft and rocket research, will continue and expand on nuclear propulsion as that field itself grows.

NUCLEAR RAMJET PROPULSION

By T. C. Merkle

The past year has indeed seen considerable progress in the program to demonstrate the feasibility of using a nuclear reactor as a heat source for ramjet-missile applications. Basically, three areas of work are critical in this program:

1. The production of a nuclear system using an acceptable amount of critical material and having a suitably controlled power distribution. In this area, it was also necessary to prove out a nuclear-control system which could realistically meet the dynamic-response characteristics of a flying machine. The successful demonstration of the Tory II-A-1 test reactor indicates the progress made in these areas.

2. The production of adequate fuel elements for the ramjet application is naturally a key problem. Since the degree of success in this area is a classified matter, progress in this area must remain shrouded in mystery.

3. A third critical area has to do with the engineering design of a reactor having suitable structural properties. Again, the operation of the Tory II-A-1 test reactor without any difficulties indicates that progress has been made, but the precise degree of such progress is again classified information.

During 1961, four reactor tests were conducted, all with the same reactor, Tory II-A-1, shown on page 128. These were run on May 14, September 28, October 5, and October 6, 1961. In all tests the power level was above 40 megawatts, the core temperature greater than 2000 F, and the operating time longer than 45 sec. In the May 14 test the air-flow rate through the reactor was 120 lb/sec.

Future plans revolve around the testing of Tory II-C, a ground-test version of a flyable nuclear reactor ramjet. Tory II-C reactor design is continuing, and reactor parts are presently being fabricated. At the NTS, construction work is in progress to increase the (reactor coolant) air supply from its present capacity of 120,000 lb to 1-million lb; this will allow test operations of increased duration and/or power level. Although projected reactor test schedules remain classified, prospects do seem bright for the development on a useful time scale of a flyable reactor configuration.

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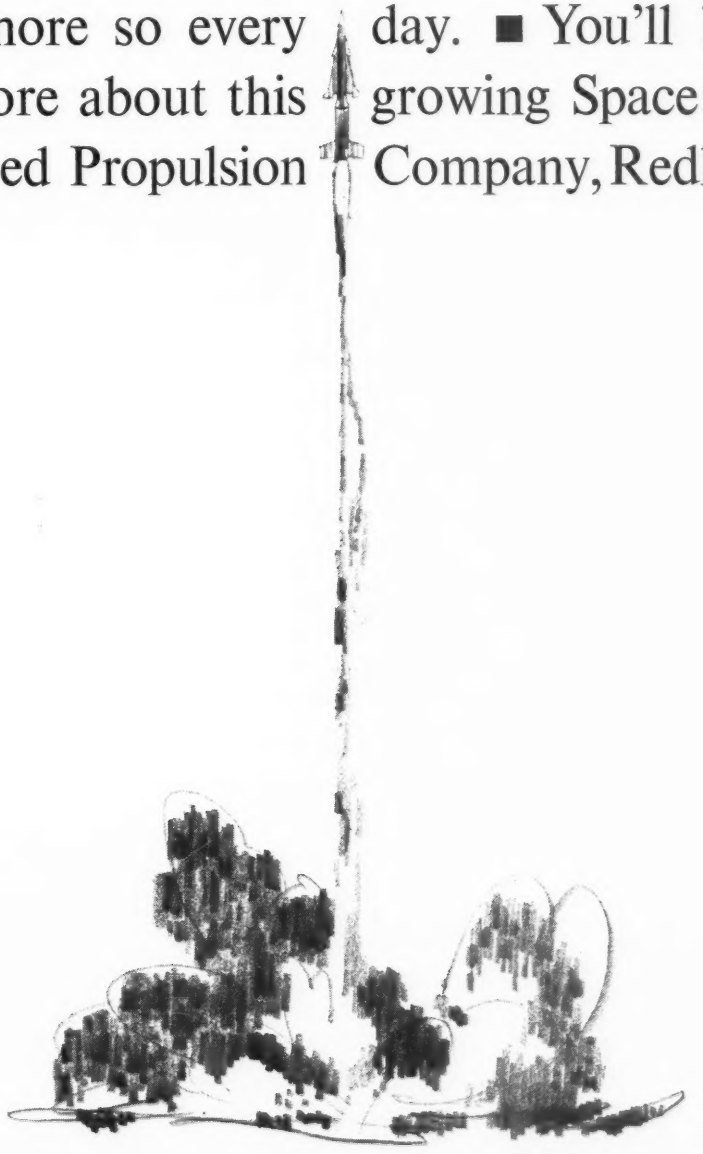

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